GUNDAPPA RADJASEKHARAN

THE PROBLEM OF FATIGUE IN RELATION TO THE PROGRAMME OF "BASIC EDUCATION" IN INDIA

A Contribution to Some Problems in the Psycho-Physiology of Movitation

With a German Summary

LUNDEQUISTSKA BOKHANDELN
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THE PROBLEM OF FATIGUE IN RELATION TO THE PROGRAMME OF "BASIC EDUCATION" IN INDIA

A Contribution to Some Problems in the Psycho-Physiology of Motivation

BY

GUNDAPPA RADJASEKHARAN

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A token of cordial esteem and a tribute

to

His Excellency Dr. Zakir Husain M. A., Ph. D., D. Litt., Governor of Bihar and Chancellor of Bihar University (India), who along with Gandhiji pioneered in building up a programme of National Basic Education for the Indian Democratic Republic.

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PREFACE

The investigation that is put forward in its present form originated some fourteen years ago during the period of my research in Jamia Millia Islamia (National Muslim University) as a Wattumal Foundation scholar under the direction of H. E. Dr. Zakir Husain, Governor of Behar (India) the then Vice-chancellor of the University. The innumerable and difficult problems which arose with the advent of Indian freedom and my own preoccupation with the wider problems of reorganization and development of "Basic Education" at the University of Santiniketan, West Bengal, and at the Rural College attached to the headquarters of Gandhian Economics, Wardha (India), prevented undivided attention being given to scientific research in this direction during the following years.

In the autumn of 1953 on my admittance to the Institution of Pedagogics and pedagogic psychology in the University of Uppsala the work was, however, taken up again and Dr. Zakir Husain and Prof. K. G. Saiyidain, till recently Secretary of the Ministry of Education and Scientific Research, New Delhi, have maintained a continuing interest. I am deeply grateful for their encouragement. During the period of my scientific research I have been in daily contact with my professor, Dr. Wilhelm Sjöstrand, chairman of the Pedagogic Institution. His wide knowledge, originality of approach and elegance of methods has deeply influenced and moulded my efforts in giving the thesis its present form. I am indebted for his personal guidance and instruction and to his Institution for providing wider opportunities to educate me to some extent. I have freely discussed the problem with Docent Peep Koort, Docent I. Dureman, Fil. Lic. K. G. Ahlström, Fil Lic. L. Holmström and Fil. Lic. G. Weldes. Fil. Lic. Ahlström helped in the earlier part of my experimental work and has gone through the manuscript. Docent C. I. Sandström has gone through the manuscript and offered good suggestions. Fil. Kand. Helena Larsson and Fil. Mag. T. Stockfelt have offered critical suggestions

relating to the psychological part of the work. Fru G. Löwgren has assisted in a number of ways in producing the manuscript.

I have freely drawn on the expert assistance in the Institutions of Biochemistry, Physiology, Anatomy, Pharmacology and Psychology. Prof. G. Ström has read the physiological part of the manuscript and I have discussed in detail the neurophysiological implications of the problem with Docent K. E. Hagbarth. Labarator K. J. Öbrink has given much of his valuable time in evaluating and discussing the physiological part of the thesis. Dr. J. Ekstedt through his experimental work and penetrating analysis of the physiological implications has deepened my approach to the problem. He and Dr. N. H. Areskoog have gone through the physiological section of the manuscript and their suggestions have been included.

Dr. K. Söderberg, Director of Uppsala Elementary Schools has given me all possible help in carrying on my extensive experiments. Head-master A. Åsblom (now retired) of the Sverker and Erik Elementary Schools has offered all the facilities for carrying on intensive experiments. "Slöjd" instructors S. Hagdahl, A. Löwling and L. Hagberg have not only helped in carrying on my experiments in wood-work but have ungrudgingly given their invaluable time in the evaluation of products.

Mr. A. D. Mills M. A. (Lond.), English Lecturer in the University has corrected the English of the thesis. Dr. G. Backenköhler, lecturer in German in the University, has undertaken the German translation of the English summary of the text.

I warmly thank all these colleagues and friends.

The "Statens Psykologisk-Pedagogiska Institut" (Royal Institute of Psychology and Pedagogics) Stockholm has met the whole cost of my experimental work and the "Statens Råd för Samhällsforskning" (Royal Council for Social Research) Stockholm has paid for the correction of the language. Without this financial assistance it would hardly have been possible to publish the thesis and I am deeply grateful to the state institutions.

Institutionen för pedagogik
Uppsala Universitet
September 1st. 1961

G. Radjasekharan

INTRODUCTION: THE PROPLEM

At the beginning of the 20th century, India was one of the educationally backward countries. The British attempts to reorganize the educational system of the country provided education for the children of kings, land-lords, and other such well-to-do privileged classes on the lines of the aristocracy of England. The educational system was based on the analogy of the "downward filtration theory"[1] that the higher classes would educate the masses. The British also had the objective of securing the services of intelligent and loyal, but low paid, servants for the urban and centralized administration within a short period of time. Therefore good educational provision and development programmes existed mostly in towns and cities. Education in the countryside suffered deeply from lack of encouragement. Meagre financial assistance[2] added further hindrance to its progress. Due to negligence the indigenous rural schools slowly disappeared, some being deliberately destroyed. "This neglect of rural education implied the neglect of mass education as well, because in India 87 % of the people live in villages."[3] Consequently "mass education ... made little progress during the nineteenth century".[4]

The close of the First World War released revolutionary urges

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[1] Saiyidain p. 13.

[2] The financial expenditure on education was 0.88 % of the total revenues during 1901–02, although "educational expenditure increased greatly under the crown" (ibid. p. 17).

[3] Saiyidain p. 17. "According to the returns of 1949 ... 300,000 villages are still without any kind of primary school" (ibid. p. 35). In Travancore, the most progressive state, only 14.2 % of the total child population attended some form of primary school. The percentage for school-going children in other states is much lower (ibid. p. 153).

[4] Ibid. p. 13.

of democratic freedom and cultural advancement which in turn called for vigorous demands for reforms in compulsory education. The gradual development of reforms, the re-orientation of education to meet the increasing demands of the people, and the final attainment of Independence, resulted in the state's undertaking "to provide, within a period of 10 years from the commencement of this constitution, for free and compulsory education for all children until they complete the age of 13 years".[5] Of the many reforms and schemes of education that were framed during the period, the plan of "Basic Education" put forward by Gandhiji[6] in the autumn of 1938 is significant and far-reaching. The scheme is considered to be based on the principle of 'activity' advocated by a number of renowned pedagogues from Pestalozzi to Dewey. However, on a closer analysis it would appear that the scheme "has some original features and represents the most important contribution to educational thought during the present century".[7] The main points of Gandhiji's scheme were the following:

"a. All children from the age of 7 to 14[8] should be given free education. b. Education should centre round some form of productive manual work and all the other abilities to be developed or training to be given should, as far as possible, be integrally related to the central handicraft. c. The productive work done by the children should have some economic value. Efforts should be made to see that the price of objects produced by children covers the salary of the teacher."[9]

Productive work, the central feature of "Basic Education", is not only a medium for the all-round development of the pupil, but at the same time the school curriculum is integrated and correlated to the Basic activity with due regard to the natural and

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[5] The Constitution of India p. 20, cf. Planning Commission (1958) p. 333.

[6] Gandhi (1950 a) p. 3 ff.

[7] Saiyidain p. 130, cf. Zakir Husain (1950) p. 12.

[8] The period of free education has since been raised to 8 years. See Ministry of Education (1956) p. 1.

It may be interesting to note that the scheme mentions no idea of making education compulsory, for "the idea of compulsion in any form was repugnant to Gandhian philosophy" (Saiyidain p. 132).

[9] Saiyidain pp. 131–132, cf. Report of the Wardha National Educational conference p. 82, Kabir p. 23.

social environments of the pupil.[1] Psychologically, productive work keeps the mind of the pupil fresh and alert "through active participation (in productive) processes"[2] involved in the large variety of tools and materials. The fact that the task performance has a purpose "initiates new ideas and makes possible new combinations of ideas already present".[3] In "pursuit of this ever-widening circle of purposes one exercises all one's powers and puts forth all one's energy"[4] in the course of which one accrues "a good deal of traditional knowledge and a good deal of mechanical skill".[5] The knowledge and skill thus acquired by a balanced and co-ordinated approach towards the intellectual and practical elements of experience is real and concrete. What is more, it replaces the otherwise theoretical and academic instruction which usually creates a general distaste and disinterestedness in the pupils.

The social content of productive work obviously recognised in "Basic Education" makes possible organised and group activities in the school. Such activities, having "an immediate social utility ... inculcate in the child a spirit of cooperation and a sense of responsibility from the very beginning".[6] Qualities of character, such as consideration, honesty, reliability, conscientiousness, independence, and helpfulness, tend to be developed. In acquiring these social attitudes the "pupils will strengthen in themselves the desire for self-improvement and social service in a cooperative community".[7] In this manner productive work as a vehicle of education attempts to develop harmoniously the manual, intellectual and emotional dispositions of the pupil, in his complete education or "the literacy of the whole personality".[8]

To begin with the scheme was put into operation in one school under the direct supervision of Gandhiji. Following this a group

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[1] Kabir p. 23, cf. Report of the Dr. Zakir Husain Committee p. 89 ff., Ministry of Education (1956 a) p. 6 ff. Köhler (1936) p. 293 ff.

[2] Kabir p. 23.

[3] Zakir Husain (1950) p. 13.

[4] Ibid.

[5] Ibid. p. 14.

[6] Kabir p. 23, Ministry of Education (1956 a) p. 12 f.

[7] Report of the Dr. Zakir Husain Committee p. 96.

[8] Ibid. p. 93.

of similar schools were set up around it and soon the example was followed in other states. The pupils of these schools showed better standards and intellectual attainments than those of the conventional type. In one of the states "repeated tests carried out by the staff of the Government Training College ... revealed that the intellectual attainments of the children reading in Basic schools are considerably higher"[9] than of those reading in conventional schools. What is more "children in Basic schools often display greater self-confidence and sense of discipline than children of ordinary schools".[1] As a result the "Basic Education" scheme won the approval of the Government of India which encouraged the state Governments to open new Basic schools and convert the conventional ones to the 'Basic' type.

With the attainment of freedom and sovereignty followed the inauguration of the First Five Year Plan with "Basic education" as "an accepted goal (forming) the foundation of the National educational policy of the age group 6–14 years".[2] The increasing experience gained in the following years speeded up the pace of development of Basic Education[3] which is likely to be further accelerated in the succeeding plans.[4] Finally the procedure may be likely to lead to the setting up of a full machinery of National

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[9] Saiyidain p. 133.

[1] Kabir p. 28.

[2] Planning Commission (1951) p. 223. For a review of the steps taken in the development of "Basic Education" during the First Five Year Plan see Planning Commission (1957) p. 253 f.

[3] Progress achieved is indicated as follows:

Year	No. of Basic schools	No. of students on rolls (in thousands)	Expenditure in crores of rupees
1951–52	33,751	29.85	5.18
1956–57	46,825	41.03	9.06

See India p. 113.

[4] The Second Five Year Plan sets the following target:

	1950–51	1955–56	1960–61
Basic schools	1,751	10,000	38,400
Enrolment	185,000	1,100,000	4,224,000
Training schools	114	449	729

See p. 506.

Education involving the provision of Basic Education for all boys and girls in the age-group 6 to 14.[5]

The importance of the "Basic Education" scheme in relation to the program of educational development and expansion is thus evident. The cultural and social significance of the scheme has had wide acceptance. Productive work, however, the core of the Basic Education scheme, has been a subject of interesting discussion and criticism. Criticism has been directed especially towards some problems related to the duration of productive work in Basic schools and "its place in the curriculum is still a matter of controversy".[6] The pioneer committee presided over by Dr. Zakir Husain[7] reporting on Basic Education recommended in general a maximum period of 3 hours and 20 minutes for integrated Basic craft in the schools out of a total time of 5 hours and 30 minutes in the daily school program. But this period of productive work in the schools varies from state to state. In

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[5] Second Five Year Plan p. 506 f., Planning Commission (1956) p. 183 ff., ibid. (1958) p. 334 f., Zakir Husain (1953) p. 234.

In drafting the Third Five Year Plan Planning Commission (1960) states that "by the end of the second plan, about 24 percent of elementary schools will be of the basic pattern. The process will be carried forward in the third plan" (p. 100).

Emphasizing the importance of trained teachers it further states that "about 70 percent of training institutions will provide training in basic education. The remaining institutions will also be so converted before the end of the third plan. All new training institutions are to be of the basic pattern" (ibid.).

[6] Kalelkar p. 65.

[7] Report of the Dr. Zakir Husain Committee p. 119.

The nature of productive work and its duration in the school varies in other countries. The 1950 Swedish school reform does not specify any exact time for "slöjd" or for "general practical training" in elementary schools. For preparatory vocational training they estimate roughly 24–30 hours a week out of a total weekly program of 40 hours. See Düring p. 80 ff. cf. Norinder p. 266 f. However, the fifth grade pupils in Uppsala elementary schools have three continuous periods of "slöjd" each of 45 minutes duration on two days a week.

The new comprehensive school has 4 hours of "slöjd" in a week of 36 hours of school work, including gardening. See Kungl. Skolöverstyrelsen p. 24. But in the lower grades of the comprehensive school there is continuous training in activities like folding, plaiting, cutting, scratching, paste work, weaving, needle work, knitting etc. (ibid. p. 52).

general it may be stated that the duration of productive work is about two hours in the day's total school program.

Productive manual work as an integral part of the "Basic Education" program, if it was not essentially new, appeared on the scene in a new form. Except for a negligible number of private and Roman Catholic schools which had manual labour on a certain day of the week's time table, it was not a regular item, much less an integral part of the educational program. Under the circumstances a good many educational psychologists considered that the introduction of this new item as the central and integral part of education was undesirable and interfered unnecessarily with the hitherto smooth and cohesive school work.[8] In particular it was observed that a daily two hour program of manual productive activity "would lead to dead monotony, to drudgery and to exploitation"[9] involving fatigue of the school pupils, especially in the age-group 6–14, who would probably not have the required capacity to stand up to such work. At the same time it created difficulties for teachers who are generally averse to manual work. It was also observed that a two hour program of productive work every day, while tending to induce fatigue, would in turn detrimentally interfere with the various mental tasks and disciplines.

Under such circumstances and in view of the fast development and expansion of Basic Education[1] an important problem would appear to be the elucidation of the nature and scope of fatigue in a two hour program of productive work daily in a school timetable. This dissertation is an attempt to discuss this problem in some detail and to offer some experimental contributions to its solution.

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[8] Zakir Husain (1950) p. 10 f.

[9] Ibid. p. 11.

[1] For literature on this comparatively new field of Education see Ministry of Education (1956 b).

PART I

THEORETICAL BACKGROUND

CHAPTER I

THE CONCEPT OF FATIGUE

Difficulties in defining the concept

Floyd[1] states that "there is little dispute about the reality of fatigue" in human task performance but that "its nature ... is but incompletely understood".[2] The obscure understanding of the concept of "fatigue" appears to be obvious because a complex of physiological and psychological influences are involved in the task processes of performance.[3] Since "fatigue" may manifest itself in almost any one or all aspects of the functional modification of the organism as a result of continued task performance "it has been found applicable in a broad field of experimental study and it includes a wide range of phenomena".[4] Ryan[5] and others[6] attempted to distinguish between distinct varieties of fatigue as would be applicable to the corresponding phenomena of task performance. Forbes[7] observed that the recognition of "many kinds of fatigue (each having) a different cause and different symptom" is desirable and that "the general tendency to speak of fatigue as an entity"[8] hindered a scientific study of the concept. However, "fatigue" presents itself in an "unstructured situation ... which permits the subject to respond to it in a practically

[1] Floyd p. V, cf. Carmichael (1947) p. 2, Bartley (1943) p. 160, Forbes (1943) p. 155.

[2] Floyd p. V.

[3] Brouha (1960) p. 109.

[4] Ryan (1944) p. 565, cf. Forbes (1943) p. 155.

[5] Ryan (1947) p. 64, cf. ibid. (1944) p. 568.

[6] Podolsky p. 380.

[7] Forbes (1943) p. 155.

[8] Ibid.

unlimited number of ways, that is, one which leaves him free to create his own structure according to his own ideas".[9] There is therefore, the possibility that the different kinds and classified concept of "fatigue" may influence the structuring and that the results may therefore be interpreted according to some preconceived meaning of the term. A theoretical classification which had not been subjected to experimental verification in terms of the physiological and psychological processes involved in task performance would not give precise meaning to the term and so Bentley[1] rightly took objection to the indiscriminate use of the term "fatigue" to denote a variety of changes which manifest themselves during continued task performance.

Viteles' definition

In attempting to avoid a wide and varied use of the concept Viteles[2] and others[3] proposed a more integrated and unified concept which appears to have had wide acceptance. According to Viteles[4] "the word fatigue, as used both popularly and scientifically, refers to three related phenomena: 1. an overt manifestation in the form of reduced output on the task, known as work decrement, 2. a physiological state, involving changes in organic functions and the production of chemical products of fatigue, 3. a feeling of fatigue or tiredness".

Quantity and quality of output

Now the first part of the definition of "fatigue" refers to the output of work decrement in some way or other depending on the "diminishing capacity for doing work".[5] This is "sometimes

[9] Goodenough p. 98. For example Ryan (1944) considered a behavioural description of fatigue to be too restrictive and "unduly limited" and stated that "the perceptive and other observable aspects of 'being fatigued'" should be noted (p. 565), while Shands (1952) observed that a satisfactory definition of fatigue "must be general enough to include those found in the chronic state" (p. 309).

[1] Bentley p. 264 f.

[2] Viteles p. 441.

[3] Ivy (1942) p. 569, cf. Bills (1937) p. 438, Ash p. 1, Yoakum p. 23.

[4] Viteles Ibid.

[5] Tiffin p. 438, cf. Ryan (1944) p. 566, Bronk (1929) p. 270.

loosely called the objective definition".[6] The concept of progressive output decrement during a period of continued task performance is sufficient for working purposes and may include all those changes in performance of the task processes which appear to be due to continual exercise of the activity only under normal operational conditions, a point of view which Viteles[7] omitted. And then we have to look upon the definition from another important aspect. In practice there may be activities whose continual exercise may present a different picture "when the normal conditions are exaggerated in some special direction, or unaccustomed environmental circumstances are present".[8] The significance of these phenomena has come to be recognized rather in recent times in experimental psychology and such activities rarely involve excessive physical or muscular effort. But these activities involve "accuracy ... considerable speed and manipulation, (and) expression in coordinated bodily movements".[9] During the performance of tasks involving a high degree of skill the subject "tends to maintain a persistent pattern of behaviour, making the necessary adjustments of acceleration, deceleration, ... change and speed of change of direction within small limits of difference relative to the over-all state"[1] of task performance. At the same time the knowledge and information the subject gathers during the task performance and environmental influences need to be "filtered, analysed and passed on in a form suitable as a basis for quick decisions and actions. It involves executive skill operating at a high level over a wide and varied area".[2] In such circumstances over-all speeding up of continuous task performance may force alterations in the timing relations of the successive phases of the task processes so that the task "performance becomes ragged and uneven, and ... will inevitably suffer from fatigue and strain".[3] Such incidental disorganisation and disruption in the task processes of performance, while in-

[6] Ryan (1944) p. 566.
[7] Viteles Ibid.
[8] Bartlett (1951) p. 630.
[9] Bartlett (1951) p. 629, cf. Woodworth (1958) p. 145 ff., Davis (1949) p. 3 f.
[1] Bartlett (1951 a) p. 211, (1943) p. 247, Welford (1958) p. 18 ff.
[2] Bartlett (1951 a) p. 213, cf. Crossman p. 899, Poulton p. 472 ff.
[3] Bartlett (1951 a) p. 213 cf. ibid. (1951 b) p. 55 f.

fluencing the quality of output, may or may not necessarily result in diminished quantity of output. Therefore a definition in terms of output must of course include both quantitative and qualitative changes.

The physiological approach

The second part of the definition of "fatigue" relates to the physiological changes involving organic functions and the chemical changes so brought about during task performance. The assumption that chemical changes in muscle accompany the exercise of any form of task performance whatsoever in a perfectly correlated manner has not received experimental support.[4] Page[5] attempted in an extensive review of literature pertaining to metabolic studies, a possible description of a decreased efficiency of work through an increase in the physiological cost of work to clarify the otherwise hazy notion of "fatigue". However, there are no signs of any attempt to relate this concept of "fatique" to efficiency of work in these physiological studies. Page's[6] attempts to work out a physiological concept of "fatigue" in terms of decreased efficiency of work were based on the work of Waller,[7] who in his experiments on energy measurements in proof readers found that both the initial level of energy expenditure and the increment of it were low and so concluded his index of measurement to be unsatisfactory for "cerebral work".[8] The failure in the attempt to relate the efficiency of performance to the physiological cost of work as "fatigue" seems to be due to the inadequacy of metabolic indices of the cost of work as criteria of "fatigue", when gross muscular activity is minimal. Forbes[9] describes experimental attempts carried out over a period of 2–3 years to establish normal values that "could measure ... blood, urine, and sweat ... normal circulation and respiration" in fatigued subjects and concluded that "nothing that we could measure

[4] Simonsen p. 318 f., cf. Dolley p. 51 f.

[5] Page 332 ff.

[6] Ibid.

[7] Waller (1920) p. CV f.

[8] Ibid. p. CVII.

[9] Forbes (1943) p. 156.

was changed significantly even though the man was tired".[1] There are a number of other investigations in metabolic equivalents of physical and mental effort which fail to show comparable increased physiological indices due to effort.[2]

It is true that Silver[3] has shown that "chronic fatigue" is due to endocrine disorders, states of vitamin deficiency and anaemic states. Such conditions are regarded as leading to physiological exhaustion and psychological frustration.[4] Organic impairment due to "chronic fatigue" however, varies enormously under different pathological conditions. In an extensive review of several physiological mechanisms involved in muscular exercise under pathological conditions Simonson[5] for instance concluded that in "chronic fatigue" "the impairment of various functions as well as the involvement of compensatory mechanisms vary in different diseases". Shands[6] therefore, found he was never able to give a definite meaning to complaints of "fatigue" from his patients in the same way as to other symptoms of the neurotic. These aspects of pathological fatigue are no doubt important in establishing a correct concept of fatigue. But the conditions of

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[1] Ibid.

[2] Benedict (1913) p. 71 ff., cf. ibid. (1909) p. 20 ff., (1930) p. 438 ff., (1933) p. 42 ff. For a detailed description of metabolic events occurring during task processes of physical and mental activity see chapters 2 and 3.

[3] Silver (1949) p. 600 f., cf. Muncie p. 285.

[4] The major explanations of exhaustion and true fatigue due to organic changes are concerned with conceptions of 'psychoneurosis' and 'exhaustion psychosis'. At the root of such pathological conditions "there are likely to be grave somatic affections ... a mixture of somatic disorder and psychological maladjustment" (Robinson (1934) p. 625) which "may be due to a poor nervous inheritence or constitutional inadequacy" (Alvarez p. 443). "True exhaustion of the nerve cells may be brought about by prolonged pathological conditions such as disease, enforced insomnia, or extreme emotional excitement" (Robinson (1934) p. 602). For a descriptive study of disorganization brought about by pathological causes see Lowenstein (1951) p. 580 ff., (1952) p. 1 ff.

[5] Simonson p. 407.

[6] Shands (1948) p. 210 f. The extensive studies of neurological complaints of fatigue have left the concept vague and diffuse. Schwab (1951) in an attempt at the differential study of fatigue distinguished fatigue symptoms according to the disturbances evident in 1. disease and damage in muscles, 2. disease in myo-neural junction, 3. in peripheral nerves, and 4. presence of excessive nerve impulses in the nervous system (p. 134 f).

exhaustion and frustration have other fundamental causes, besides that of over-work alone, involved in the organic impairment. There is a series of conditions present in between the states of physiological exhaustion and psychological frustration in our daily task performance which is something totally different from general break-down due to exhaustion resulting from organic impairment. We have, for example, a tendency to break-down due to organic changes in the co-ordination of eye movements as shown by Dodge[7] or in the finger alternating movements as investigated by Robinson.[8] Such break-downs are due to loss of balance and are not the result either of great demands upon energy resources or of strong concentrations of fatigue products. They may be due either to the existence of undesirable competing responses of a strength almost equal to that of desired responses claiming priority or, to a disorganisation of skills and special functions involving a balance between task processes of varying speed, extent and direction.

Experimental work on repeated stimulation of nerve muscle preparations, the ergograph[9] and prolonged performance of industrial tasks is considered to result in diminished response due to prolonged task performance. But according to Rosenbluth[1] the definition of 'fatigue' as "progressive decrease of response resulting from previous activity (is) vague (as it) includes all the stages of depressed activity". He used the term only as applied to his 2nd stage, i.e. the neuromuscular transmission. A number of other experimental investigations show in addition that "the classical fatigue curve developed in Mosso-ergograph[2] is not

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[7] Dodge (1923) p. 169 ff., (1913 a) p. 1 ff.

[8] Robinson (1926 a) p. 437 f.

[9] Poffenberger (1942) p. 113, cf. Carmichael (1947) p. 5 f.

[1] Rosenbluth p. 149. According to him "theoretically ... at least four different types of neuromuscular fatigue may exist: a. fatigue of the nerve, b. transmission fatigue, c. fatigue of the muscular conducting system, and d. contraction fatigue" (p. 150).

[2] Mosso's contention that the fatigue state is reached when no more contraction occurs during ergographic work is contested by Schwab (1951) who observed that "in numerous adequately controlled observations reported in the literature and repeatedly confirmed by us, it has been possible by electrical stimulation to cause the muscle to contract promptly at the point when voluntary fatigue is complete" (p. 133, cf. Osgood (1953) p. 341).

typical of the way in which normal adult human subjects, at varying levels of motivation, respond in situations requiring continuous activity".[3] In connection with the intervening factor of motivation Myers[4] states that "fatigue of direction is of far greater importance than fatigue of act". He means that it is important to investigate the nature of task processes involving "manifestations of ... attitudes of attention etc.,"[5] which are dependent on the direction and adaptation of activity. In stating the distinction between adaptation and fatigue Myers[6] points out the importance of 'sets' or attitudes in the subject during the task processes of performance. His discussion of 'sets' or attitudes suggests that adaptation is a change in the readiness of the subject to react during continued task performance. Then fatigue may be considered as an active interference or inhibition observed when competing responses are set against each other.[7]

Fatigue from the psychological point of view

The last part of the "fatigue" concept is said to involve feelings of tiredness. Forbes[8] observed that a subjective definition of fatigue is inadequate, for in that case "the door is opened to endless unverifiable verbalizations which get nowhere". For instance, fatigue sensations are certainly regarded not only as influencing task performance in a general way but also as affecting the nervous impulses travelling over efferent paths, thus influenc-

[3] Carmichael (1951) p. 96. He has also reviewed a number of such experimental studies (p. 94 ff., cf. Ryan (1944) p. 566). The manifestation of psychological control of output instead of the physical one during task performance is shown by Forbes (1943) p. 157.

This motivational element is also responsible for the "specific loss ... of the ability to initiate activity" that patients complain about (Shands (1952) p. 309).

[4] Myers (1925) p. 16.

[5] Ibid.

[6] Myers (1937) p. 303, (1925) p. 6 ff. Harris demonstrated that "in fatigue, the duration of the stimulating tone has a cumulative effect ... while in adaptation the effect of duration of stimulation is not cumulative within the rather wide limits ... for these reasons adaptation must be considered as at least a special case of fatigue: if it is not indeed a separate phenomena altogether" (p. 457).

[7] Myers (1937) p. 303, cf. Ash p. 11 f.

[8] Forbes (1943) p. 156.

ing the performance output.[9] But experimental support for such a view is scanty and ambiguous. Bartley[1] emphasized the feeling states of "fatigue" otherwise known as the subjective aspects of "fatigue". "The subjective constituents that come into the picture", he writes, "are not to be taken ... as symptoms of fatigue, but as fatigue itself. If subjective elements which constitute a picture are non-existent in the situation, there is no fatigue."[2] In connection with this overemphasis of the subjective definition of "fatigue" Bartley stresses the importance of conflict in the constituent phases of "fatigue" feelings by using phrases like "an overall state ... of the person as a whole (and) one form of attempt to retreat or escape from a situation".[3] In this all-inclusive and vague concept[4] of feelings of fatigue it is of course not difficult to see how the feelings related to activity in muscle processes and to the reparative mechanisms of the organism may also be "related to conflictive activity at a psychological level".[5] Psychological feelings of fatigue "may be due to boredom, nostalgia, anxiety or emotional reaction"[6] which may interfere with task processes of performance or they may be a factor in the "diversion of nervous energy into unhealthy channels, such as worry and lack of proper motivation ... associated with chronic anxiety and depression".[7] In the latter case "fatigue (may) function in patients ... as a psychoneurotic symptom".[8] In a paper with Gross,[9] Bartley considers feelings of fatigue to be something different from impairment, and impair-

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[9] Cason (1935 a) p. 215, cf. Bronk (1929) p. 280.

[1] Bartley (1945) p. 169 f.

[2] Ibid. p. 169.

[3] Ibid. (1947) p. 53, (1943) p. 160 f., (1957) p. 319.

[4] Yoakum in an extensive study of fatigue vaguely identifies sensations and feelings of fatigue with nervous fatigue and at the same time with weariness due to monotony (p. 44 f).

[5] Shands (1952) p. 310.

[6] Harms p. 312. cf. Kimber p. 216 f.

[7] Ibid. pp. 312–313. cf. Kimber p. 216 f.

[8] Shands (1952) p. 313. Schwab (1951) states that "In ... neurosis fatigue is generalized, vague and diffuse ... it is often associated with psychiatric symptoms and words like lack of desire, lack of ambition, irritation, boredom, are commonly used" (p. 135, cf. Shands (1948) p. 210 f., Silver (1949) p. 602, Muncie p. 284 f.).

[9] Gross p. 205, cf Bartley (1947) p. 53, (1943) p. 160.

ment is understood as a measurable decrement in task performance associated with metabolic processes of effort. He fails, however, to explain the nature of the difference between feelings of fatigue and impairment. Bartley[1] also states that "neither fatigue nor impairment can be measured by the work output of the intact organism" and so appears to object to an output definition of fatigue. Bronk[2] has shown that conditions and activities governing sense organs in muscles influence the sensations from the muscles and through the sensations many reflexes of the organism. Thus there are possibilities of fatigue sensations influencing task processes and the consequent output. As observed by Seashore[3] subjective states of feeling "may arise from physiological impairment of tissues during exercise, or it may be largely a conditioned response, e.g. boredom. Likewise work output may decrease as a result of either of these two factors (or both). Conversely, under conditions of adequate motivation, physiological impairment . . . may not result in either feelings of fatigue or reduced work output". One can therefore conclude that to define "fatigue" in psychological terms is as impossible as to define it in purely physiological terms.

An operational definition and its advantages

It is apparent that the fatigue concept as generally understood in the three-fold meaning of a measurable output decrement, as changes in neural and organic states or as a state of subjective feeling is open to considerable objections. The different sides to the definition of the term "are not closely related, some of them have little in common"[4] and so this definition has led to confusion and vague expression.[5] Dill,[6] studying the physiological mechanisms involved in the alterations of the physicochemical states of the individual, concluded that "there appears

[1] Bartley (1947) p. 49, Gross p. 205.

[2] Bronk (1929) p. 280.

[3] Seashore (1951) p. 1358. For a descriptive analysis of the nature of feeling tone and its influence on output changes see Thorndike (1926) p. 124 f., Muscio (1921 a) p. 160 f.

[4] Dill (1936 a) p. 417.

[5] Carmichael (1947) p. 2.

[6] Dill ibid. p. 430.

to be little prospect of developing a simple and adequate hypothesis regarding the origin and nature of fatigue". The attempt to define the concept with precision[7] has failed in as much as the term "is applied to any of a series of states running all the way from true physiological exhaustion to psychological frustration uncomplicated by any detectably somatic disorder".[8] A review of a large number of different concepts of "fatigue" discussed by Bartley[9] and others[1] reveals that a rigorous definition which can be generally accepted has never been devised.[2] Watson,[3] in fact, considered the concept of "fatigue" for psychological discussions to be "confusing and worthless" and Davis[4] thought it fit to "dispense with the term" due to haziness in meaning.[5] This unfortunate situation has prevented the solution of a number of practical problems. Watson[6] however, suggested a more "constructive" approach. "The point we would make in doing behaviour work", he says, "is to leave out of discussion all those factors which are not touched or approached by the problem in hand: for example, what possible good does it do when discussing brick-laying or sub-vocal arithmetic to guess at what goes on in the synapse, in the efferent or afferent leg of the reflex arc or in the muscle itself?"[7] Watson's[8] criticism is not based on the erroneous nature of such approaches but on the fact that they happen to be just theories. His contention would appear to be to tackle practical problems in a situation, for example the loss of efficiency in output or "under what precise conditions errors occur".[9] Nevertheless one can attempt to build up a scien-

[7] Brouha (1960) p. 109, Muscio (1921) p. 31 ff.

[8] Davis (1946) p. 28.

[9] Bartley (1957) p. 301 ff., (1947) p. 5 ff.

[1] Carmichael (1947) p. 6 ff.

[2] Otani p. 272, cf. Brouha (1954) p. 9, Bartley (1943) p. 160.

[3] Watson (1929) p. 379.

[4] Davis (1947) p. 44, cf. Muscio (1921) p. 45.

[5] Davis (1953) p. 179, (1946) p. 28, Page p. 332. Henley says "whether (we) speak of fatigue, tiredness, lassitude, lack of energy, exhaustion, weariness, sluggishness, lethargy, languor, lack of pep, being browned off, or having had it, the meaning is in all essentials the same" (p. 213).

[6] Watson Ibid.

[7] Ibid. p. 382.

[8] Ibid.

[9] Davis (1947) p. 44, cf. Scherrer (1960) p. 490 f.

tific concept of "fatigue" in another way than by defining it in physiological and/or psychological terms. As we have seen "fatigue" has generally meant to the psychologist "some kind of change taking place in the organism, which is indicated ... by changes of feeling and behaviour, but which does not strictly consist in them"[1] while to the physiologist the concept meant "some kind of reduction of response following more or less prolonged activity (where) the mechanism in some way becomes insensitive or inert".[2] Under such circumstances fatigue may simply be understood to mean "all those determinable changes in the expression of an activity which can be traced to the continuing exercise of that activity under its normal operational conditions, and which can be shown to lead, either immediately or after delay, to deterioration in the expression of activity, or, more simply, to results within the activity that are not wanted".[3] In other words output and output changes are signs of different processes which should be further investigated in order to come to a fuller understanding of the whole phenomenon.

An output criterion of fatigue which "does not in any way preclude the concurrent use of physiological or psychological variables"[4] has obvious advantages. It easily lends itself to quantification "which allows mathematical treatment"[5] and so experimental investigations may be conducted with convenience and significant meaning. In the day-to-day progress of business, factory and school work, the criterion of performance output has been useful as a measure of loss or gain in the efficiency of task performance. In schools especially psychologists do frame tests consisting of some form of physical and mental computation with a fair amount of success which could serve as a convenient and significant measure. With the help of such output tests and by controlling variables like practice effect, the difficulty of task, minimum physical effort, and sensory strain etc., one is able to

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[1] Welford (1953) p. 183.

[2] Ibid.

[3] Bartlett (1953) p. 1. It is very important to observe the expression "under its normal operational conditions" and the word "deterioration", because this makes a difference from the output definition of Viteles (Ibid).

[4] Tiffin p. 441.

[5] Otani p. 272, cf. Dodge (1913) p. 7.

study "a genuine and comparatively isolated problem ... largely free from interfering factors".[6] One may of course still attempt to understand and interpret the fluctuating efficiency of the pupils in conjunction also with those other factors of task performance through an output curve.[7]

However, the criterion of fatigue of output changes as a means of understanding human behaviour may sometimes be misleading due to the wrong approach regarding its implications. Output decrement that may result on one occasion from a period of continuous task performance has been quite simply equated with an erroneous conception of fatigue.[8] Johnson[9] took objection to such a numerological definition of "fatigue" and maintained that statistical results of tests, for example of drivers' skill in relation to road accidents, are sometimes identified "wholly by presupposition"[1] with something illicitly called fatigue. Kraepelin[2] and his school, in an elaborate study of the work-curve, resolve the output curve into supposed features of "Uebung, und Ermudung, Gewöhnung, Anregung und Antreib".[3] These features of the output curve have been overemphasised and appear to be an "attempt to treat output curves as pure fatigue curves".[4] Thorndike[5] has subjected such description of work-curves to severe criticism. It appears to be his main contention that warming-up, initial spurt, and the like, are fictitious and theoretical assumptions used to describe the irregularities present in the work-curves. On the other hand these conceptions of the output curve need empirical investigation. Output measures as products of physical and mental work deal with the different and varying

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[6] Farmer p. 314.

[7] Ibid. p. 309, cf. Chapman (1915) p. 424.

[8] Valentiner (1941) in her studies limited her experiments to tasks which had previously shown a reliable decrement with time (p. 61). In another study her inference of an observed phenomenon in certain tests using vitamin B. ingredients may be referred to the same unidentified factor (ibid. (1943) p. 394).

[9] Johnson (1943) p. 555 ff.

[1] Ibid. p. 558.

[2] Kraepelin p. 489.

[3] Ibid.

[4] Farmer p. 309.

[5] Thorndike (1926) p. 47 ff., (1912) p. 165 ff.

phases of the task processes of performance. Evidently the varying constituent elements involved in the task processes influence the resulting output and are to some extent determined by it. Robinson,[6] with the aid of output measurements, explained the constituent characteristics of the homogeneity and heterogeneity of task processes. Output curves have been helpful in measuring and interpreting variation in efficiency,[7] ability, practice, accuracy of work, individual differences in susceptibility to "fatigue", intelligence and scholastic ability[8] and fluctuations of attention[9] termed as 'oscillations'.[1] Experimental inquiries in industry by utilizing statistics of output and output curves have evaluated the rate of absenteeism, working conditions, industrial relations, safety, the effect of incentives[2] and their influence on work as a part of social change.[3] Viteles[4] cites the interesting unpublished investigations of Yochelson who obtained variations in output curves from several subjects extending over many days. After a degree of initial irregularity in the output curve each subject settled down to produce his own type of work-curve, and the output curve was fairly constant for each individual. "Introspective evidence shows the existence of a 'state of mind' confirming to the shape of the curve."[5]

This suggests that output and output changes as criteria of fatigue would neither mean nor be treated as simple numerological products of a period of task performance. On the other hand output and its changes are a "sign"[6] of "fatigue", "the nature of (which needs) to be appraised"[7] and determined through an analytical understanding of events which occur in the course

[6] Robinson (1926 a) p. 443.

[7] Marsh p. 4 ff.

[8] Flügel p. 14 ff.

[9] Warburton p. 162 f.

[1] Entwistle p. 313 ff., cf. Philpott (1934) p. 221 ff., (1932 a) p. 380, (1932) p. 1 ff., (1929) p. 383 f.

[2] Schwallenbach p. 58 ff.

[3] Whitehead (1938) p. 33 ff., (1938 a) p. 3 ff.

[4] Viteles p. 445.

[5] Ibid.

[6] Goodenough p. 98. According to Stevens, in output measurement we deputize the numerals to serve as representatives for a state of affairs in behaviour p. 22 f.

[7] Goodenough ibid.

of the various changing phases of behaviour involved in "the biophysics of neural activity, the chemistry of muscles, and every other factor that may be studied ... in terms of all the processes of the personality".[8]

Physical and mental fatigue as descriptive distinctions

Now in controlling behavioural changes through output measurements, physical and mental task performances are usually mentioned. There is a general tendency to regard manual work and its product of output as something different from mental work (in the sense of pure nerve-processes) and its resulting output.[9]

The difference between manual and mental task performance may be referred to in the more recent[1] neurological and neurophysiological literature describing "the motor system ... as a functional and isolated whole while many pages later we find the sensory system similarly treated".[2] Some even go to the length of describing "the motor path ways as something that goes down and sensory path ways as something in the opposite direction".[3] Livingston[4] pleads for a re-examination of such thinking and finds no biological dividing line between 'sensory' and 'motor' mechanism and states that such a "division is really one in the

[8] Carmichael (1951 a) p. 70, cf. Floyd p. VI. The scattered literature pertaining to fatigue and its relation to the psycho-physiological concomitants of task performance has recently been reviewed by Bartley (1957) p. 301 ff.

[9] Forbes (1943) p. 156.

[1] The earlier investigators Bastian p. 327 ff., Jackson (1958) p. 37 ff., (1958 a) p. 129 ff., Golla (1921) p. 115 ff. have emphasized the sensory component of motor behaviour and the same thought is inherent throughout Sherringtonian physiology. See for example in selected Writings of Sherrington by Denny-Brown (1939) p. 31 ff.

[2] Goody p. 312. Fulton limits the "motor area" to "area 4 ... the region of greatest excitability and also the region essential for isolated motor responses" (p. 371). He attributes the excitability of the "motor area" to "the gigantic cells of Betz", in other words as determined by its cellular structure and not by its electrical excitability (ibid.). See also Morgon (1950) p. 292 ff.

[3] Goody p. 312. Gardner (1958) observes that "those impulses that travel toward or into the central nervous system are sensory or afferent: those that leave are motor or efferent" (p. 28).

[4] Livingston p. 182.

physiologists' mind".[5] Walshe[6] agrees with this view. The recent work of Denny-Brown[7] and Terzuolo[8] emphasizes the sensory aspect in cortical motor behaviour especially in those reactions which utilize contact as an adequate stimulus namely, grasp reflex, instinctive grasp reaction and contact placing.[9] The main feature of these studies to which they draw our attention is "the manner in which these afferents with their central nervous system connections contribute to the final motor act".[1] Several experimental studies in neuromuscular performance report a relation between pulse and blood pressure changes,[2] skin conductance,[3] and such other physiological changes in the organism that accompany task performance.[4] Other studies in skeletal muscles,[5] and Jacobsen's[6] extensive experimental investigations into electrical measurements of neuromuscular states, establish a close correlation between muscular and mental work during task performance and it is considered that "muscular tension is not merely an irrelevant concomitant but is an essential element in stimulating and directing the thought process".[7] So it appears absurd to treat manual and mental activities as two different

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[5] Ibid.

[6] Walshe p. 335 f. He considers that a fallacious approach to the independence of sensory and motor mechanisms leads to confusion in understanding the role of the physiology of motor functions (ibid., cf. Goody p. 312 ff.

[7] Denny-Brown (1959 p. 793.

[8] Terzuolo p. 798.

[9] Denny-Brown (1952) p. 402 ff., (1951) p. 49 f. (1950) p. 12 ff.

[1] Twitchell p. 249, cf. Otani p. 272, Cason (1935) p. 341 f. Mott observed that "the afferent impulses, both from the skin and from the muscles, especially the former, as related to the palm and sole, are necessary for the carrying out of 'highest level' movements" (p. 488).

According to Weiner the interpretations of bodily functions as servomechanisms represent in a simple and direct manner the importance of the correlation of motor activity and the corresponding sensory function (p. 113 ff.).

[2] Gellhorn p. 239 f., cf. Day p. 333 f., Gillespie p. 425 ff.

[3] Darrow p. 747 f., cf. Sears p. 11 ff.

[4] Geildreich p. 26 f., cf. Davis (1957) p. 732 f.

[5] Bills (1927) p. 249 f., cf. Clites p. 722 f., Freeman (1931) p. 431 ff.

[6] Jacobsen (1931) p. 209, (1930) p. 606 f., (1929) p. 188.

[7] Bills (1937) p. 442.

and distinctive entities.[8] Ryan[9] interpreted work by one term "sedantory . . . (mental) work". But under this term he included activities of a diverse character as e.g., the solution of mathematical problems at one extreme and wood-work and machine operations involving motor skill at the other. If we avoid undue emphasis upon the two extremes of work continuum, there ranges a multitude of tasks between the concentrated effort of pure muscular work as e.g. ergography and the pure mental work of silent mental multiplication.

Thus output changes as criteria of fatigue during a period of performance inherently reject the dichotomy of physical and mental events[1] even as they avoid, as pointed out, varieties of fatigue. However, in relation to the total performance of the organism the pattern of events may immediately and to a greater extent be a result of muscular processes at one time and of the neural processes at another. In such circumstances a critical and empirical approach towards the factors involved in the efficiency of specific productive activities may attain some importance in regard to their analytical interpretation and complete understanding. As an aid in explaining those specific factors it would appear desirable, for descriptive purposes, to recognize the existence of physical and mental output.[2] In other words it is suggested that the distinction between physical and mental output and its variations as criteria of fatigue during a period of continuous task performance be retained "for purposes of ready description".[3]

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[8] Cason (1935) p. 338. Viteles says "as a practical matter ... there appears to be little difference between so called muscular and mental fatigue" (p. 453).

[9] Ryan (1947) p. 64.

[1] Bitterman p. 573.

[2] Cason (1935) p. 342.

[3] Robinson (1934) p. 573.

CHAPTER II

THE PHYSIOLOGICAL BACKGROUND MUSCULAR FACTORS INVOLVED IN OUTPUT VARIATIONS

The major part of studies and experimental investigations of output and its variations during a period of continuous task performance is associated with muscular performance because of the obvious advantage involved in obtaining the resulting product. We may, therefore, attempt to understand the muscular factors and processes involved in the output changes during continuous task performance.

Contraction and heat

Physiologically, output and its changes are the result of muscular contraction[1] processes of the organism involved in move-

[1] Lenman (1959) states that "unfortunately little is known about ... the physiological changes which (muscular) exercise produces" (p. 191). Huxley's (1956) recent studies of the structure of striated muscle during contraction indicated that the two principal structural proteins Myosin and Actin, separately present, alternate along the length of muscular filaments which—whatever the explanation of the movement may be—"slide past each other, and the changes in the microscopically visible appearance are those which we should expect" (p. 173, cf. ibid. (1957) p. 260 ff). During the sliding activity the "connection between the actin and myosin filaments would generate tension" inducing the muscle to contract (Huxley (1957) p. 302, (1959) p. 403 f.) cf. Szent-Györgyi p. 14 ff.

Explaining the chemical and mechanical interactions involved in the sliding of muscular filaments Weber (1959) says "that contraction ceases completely as soon as the interaction between Actin and Myosin has been stopped: and that part of the ATP splitting that does not depend on this interaction is irrelevant to contraction" (p. 420, ibid. (1958) p. 31 ff). The nature of the relationship of the sliding processes of the two principal protein elements to metabolism is still obscure and is the subject of experimental research.

ment and effort during task performance. During the contraction processes heat is liberated, "due to the release of chemical energy from the actomyosin complexes as they rearrange their chemical bonds".[2] The chemical reactions[3] underlying the liberation of heat during contraction are "unspecific"[4] and therefore the in-

[2] Guyton p. 59.

[3] The nature of chemical reactions involved in the "contractile process itself is still unknown" (Baldwin p. 408, Guyton p. 807, Hill (1960) p. 897), because "the available knowledge as to the anatomy of the motor unit is surprisingly limited" (Buchthal (1957) p. 18), and the quantitative importance of the territory of motor unit in human muscle with reference to "the small motor nerve system supplying the intrafusal fibre, multiple innervation of the single muscle fibre (and) peripheral sprouting ... is not yet evaluated" (Buchthal (1959 a) p. 125, cf. Jewell p. 46 f. Brown's (1960 a) recent investigations point out the possibilities of "the existence of polyneuronal innervation" of skeletal muscle units (p. 456).

However, it is stated that on the arrival of a nerve impulse near the muscle fibre, a localized end-plate potential is initiated at the myo-neural junction and the "current flow from the e.p.p. in turn stimulates the muscle fibre" to contract (Gardner (1958) pp. 144–145, Huxley (1958) p. 436 f., Katz (1956) p. 210). According to Csapo (1957) it is the combined action of depolarization and internal current flow which elicits contraction (p. 280 f., ibid. (1959) p. 453 f.). But Knudsen states that such observations "were on isolated single fibres (and) could not be produced when applied to muscle" (p. 378). He holds that "it is membrane depolarization which initiates contraction" (ibid). But the membrane depolarization is an involved affair and according to Buchthal (1957) "the extent of innervation zone, the scatter of the end-plates within it and the different arrival time of the action potentials from the individual fibres which emerges from it determine largely the way in which the component potentials of the motor action potential summate" (p. 28).

During contraction processes a transmitter agent acetylcholine (Ach) is also discharged in small quantities (Gardner (1958) p. 145, Guyton p. 47, Cambridge p. 462). In short according to Castillo (1956) the sequence of events that "intervene between the arrival of a motor nerve impulse and the contraction of the skeletal muscle fibre (is) nerve impulse $-^{1}\rightarrow$ acetylcholine $-^{2}\rightarrow$ end-plate potential $-^{3}\rightarrow$ muscle impulse $-^{4}\rightarrow$ contraction" (p. 137, Rosenbluth p. 150). These steps intervening between the arrival of nerve impulse and muscle contraction are grouped under the term "excitation-contraction coupling" (Csapo (1959) p. 453 ff., Huxley (1959 a) p. 446 ff., Buchthal (1959 b p. 422 ff.).

The presence of excess potassium in the muscle cells tends to increase the duration of the muscle action potential and "thus increase the contraction time and the strength of contraction of muscle fibre" (Walker (1948) p. 72, (1947) p. 22).

[4] Hill (1956) p. 175, (1953) p. 314.

fluence of chemical events governing heat liberation during muscular contraction is relatively obscure. For the sake of clarity one can classify the contraction processes associated with heat production as a. activation heat, produced during the muscle's transition from rest to activity, b. the development of tension, c. the shortening of the muscle, d. the performance of external work, e. the maintenance of tension, f. the relaxation, and g. the recovery.[5] Now the development of either tension or shortening of the muscle resulting from the contraction processes[6] is accompanied by heat production. One speaks of initial heat and a delayed heat or a recovery heat, the latter being relatively slower and accompanying the restoration of the muscle to its original state when the contraction is over.

The 'heat of shortening'[7] due to the shortening of the muscle fibres during contraction processes "is perhaps due partly to viscous friction in the muscle and partly to the elimination of heat from the actomyosin molecules as their polar structures move toward each other",[8] thus releasing energy as the molecules move to closer contact. But it would be apparent that during task performance muscle contraction processes must liberate comparatively more energy if the released energy has to manifest itself as work. In that case "provided the amount of shortening is kept constant, the work can be varied over a wide range without any effect on the heat".[9] So it follows that the magnitude of 'the heat of shortening' "is independent of the load lifted, the rate of shortening, or the temperature (but) is solely a function of the amount of shortening".[1]

The 'maintenance heat' related to the maintenance of muscle tension "is presumably the result of continued chemical reactions that are responsible for the muscular contraction".[2] In this state

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[5] Bard p. 915.

[6] According to Ruch "in physiologic language 'contraction' refers to a series of internal events which are manifested externally by either shortening or tension" (p. 101).

[7] This heat "is not generated if the fiber contracts isometrically" (Guyton p. 59).

[8] Guyton p. 59.

[9] Bard p. 916.

[1] Ibid.

[2] Guyton p. 59.

"part of the energy expended is proportional to the duration of the stimulus" and even to the heaviness of the load.[3]

With the release of tension in the muscles during the relaxation phase Hill's investigations[4] show no involvement of heat as there is no energy expenditure by the muscle because "relaxation is purely a passive phenomenon".[5] However, some heat is released during this period "that comes from potential energy stored in the muscle during the active phase of contraction".[6] Also during the restoration period when the muscle changes itself to its original state, the large quantities of stored chemical potential energy may be utilized for replenishing the energy spent during the active phase of contraction processes.

From the foregoing it may be concluded that during muscular performance the production of heat associated with the transition from rest to active state of contraction, its maintenance and back again to the original state[7] cannot be dangerous for continuation of the task performance.[8] Nor is the heat produced absolutely proportionate to the performance load, because, for example, as will be seen later there are other conditions claiming consideration, especially the training level of the muscle.

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[3] Bard pp. 916–917.

[4] Hill (1950 a) p. 43, (1953 a) p. 504 f., (1956) p. 175.

[5] Bard p. 917.

[6] Ibid.

[7] The remarkable pliability of the body in adapting itself to changing environment and climatic conditions in accordance with the physiological mechanisms involved by the maintenance of a constant internal body temperature is discussed in detail by Robinson (1949) p. 193 ff.

[8] "In a good proportion of all the experiments made" says Hill (1960) "the heat found in the muscle in the end, was no greater than the work put into it. The muscle itself apparently had produced no heat at all of its own, although it had resisted the stretch very strongly" (p. 899).

Buchthal (1944) pointed out that "even in experiments involving heavy work which has strong influence on the rectal temperature the rise in temperature is so slow that its significance to the work in many instances may be illusory" (p. 256).

Renbourn observed negligible rises in temperature after training exercises and boxing tests using 32 boys from 12–14 years of age. The slight rise in temperature over resting levels is ascribed to "emotional hyperthermia (which) phenomenon appears to decrease with age" (p. 170).

Depletion of energy-holding substances and waste products

In addition to heat liberation the task performance involving organic movement and effort causes a depletion of energy-holding substances in the organism during the processes of energy transformation.[9] The importance of the dynamic equilibrium, which is closely related to the dual phases of the metabolic process of power consumption and energy interchange in the human organism during task performance, is well recognized.[1] This equilibrium

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[9] The source of energy is the "adenylic acid system", the store-house of energy in available chemical form. The functional elements of the muscle cell take up this potential energy and transform it into mechanical work (Guyton p. 801, Mommaerts (1959) p. 1316 ff.). Incidentally it may be noted that the adenylic acid system is the source of energy for every other function in the body "such as secretion, absorption, development of membrane potentials etc." (Guyton p. 811). For a diagrammatic illustration of the adenylic acid system see ibid. p. 806, Baldwin p. 410 ff.

The adenylic acid exists in the cells of the body as adenosine triphosphate (ATP) and the breakdown of ATP is considered "to be the most immediate known source of contraction energy" (Baldwin p. 406, Weber (1958) p. 3 f., Korey p. 66, Needham (1950) p. 48). Mommaerts (1950) cites a number of experimental findings in support of this fact (p. 50 ff.). However, experiments have not so far demonstrated "any direct decomposition of ATP in a stimulated muscle" (Baldwin p. 408, Guyton p. 804, Hill (1950) p. 6 f., (1960) p. 897) because complex experimental difficulties are involved and the decomposition of ATP could not be traced "until the muscle has reached a very advanced stage of fatigue and is on the very threshold of vigour" (Baldwin p. 408, Hill (1950 a) p. 73 ff.). Further "whether this compound ATP is required to maintain relaxation or provides the energy for a single contraction or acts directly, indirectly, or not at all, involves questions that remain to be investigated" (Davies (1959 a) p. 474).

Phospho creatine present in the cells is another source of energy. But it acts more as a "buffer system" storing the extra energy from the adenylic acid system and giving it back for formation of new energy-rich phosphate bonds (Guyton p. 803, Bozler p. 68 ff.). For more details of ATP and phospho creatine (PC) reactions see Needham (1956) p. 195 f., Dubuisson p. 109 f.

According to another theory, the energy for contraction is derived from actomyosin, the actual contractile protein in the muscle cells and not from ATP (Weber (1959) p. 410 ff.). In that case energy released from ATP would be utilized for the reconstitution of "the actin and myosin molecules into active states" (Guyton p. 808).

[1] Otherwise known as "homeo-stasis". For a detailed account of present views of energy interchange see Wenger p. 16 ff., Bell (1956) p. 152 ff., Guthrie (1950) p. 8, cf. Cannon (1932) p. 24 ff.

is the balance between the supply of energy-producing material and the rate of energy consumption in the course of a given period of muscular task performance. Absence of this equilibrium or "a failure between the supply and demand may lead to that decrement in performance and in output which has been defined as fatigue".[2] In the course of energy interchange in the human organism there is a formation of fatigue substances,[3] lactic acid[4] and CO_2.[5] The output limitations resulting from a period of muscular performance are, therefore, governed on the one hand by the presence of energy-holding material with an adequate supply of oxygen to energise the material, and on the other by the quantity of fatigue substances, lactic acid and CO_2 present in the blood. The latter being injurious to the organic system, may inhibit the task processes of performance. Weston[6] ascribed the limitation of output to such "local accumulation of 'waste products' of muscle activity or ... to an increased production of antistimulant substance, or to a local exhaustion of the supply of the excitatory transmission agent itself".

The precise nature of 'fatigue substances', sometimes identified with 'waste products', is rather obscure[7] and so far experiments have not demonstrated "chemically any substance which deserves the name of fatigue substance".[8] Lee's[9] hypothesis is that "the physiological action on skeletal muscle of each of the commonly

[2] Hemingway (1953) p. 69.

[3] Otani p. 276.

[4] Baldwin p. 399 f., Schwab (1951) p. 134, Hill (1923) p. 140 ff., Fletcher (1907) for the first time in experiments on frog muscle demonstrated that quantities of lactic acid are formed on muscle contraction accompanying fatigue (p. 301 ff.). Meyerhof's (1921) further extensive studies showed a proportionality between lactic acid production and work done under anaerobic contraction (p. 164 ff., ibid. (1920) p. 245 ff.).

[5] Baldwin p. 424, Schwab (1951) p. 134.

[6] Weston p. 122, cf. Kimber p. 132 f., Robinson (1934) p. 602 f.

[7] Lee (1907) identifies 'fatigue substances' with "carbon dioxide, monopotassium phosphate and paralactic acid" (p. 171, ibid. (1907 a) p. 269). While Otani considered the fatigue substances to be "some kind of abnormal intermediary metabolites and ... inorganic ions" (p. 276), Dolley identified 'waste products' with "sarcolactic acid and monopotassium phosphate" (p. 52), and Karpovich identified "waste products (with) lactic acid, carbondioxide and acid phosphates" (p. 238).

[8] Otani p. 276, cf. Dill (1936 a) p. 417.

[9] Lee (1907) p. 178, (1907 a) p. 280.

recognized fatigue substances, namely, carbon dioxide, paralactic acid and monopotassium phosphate, is of two opposite modes ... if present in small quantity, or moderate quantity for a brief time, it causes an augmentation of activity, which is characterized by an increase in irritability and working power ... and an increase in the total work performed ... if present in moderate or large quantity, or in smaller quantity for a longer time, each substance causes a depression of activity, or fatigue of the muscle, which is characterized by a decrease in irritability and working power ... a decrease in the total amount of work performed". Experimental support for such a view is lacking. Otani[1] considered 'fatigue substances' to be "the presumable products of over-worked muscles", i.e. due as much to "over strain of the mechanism for mobilization of the glycogen reserves as to undue concentration of metabolites".[2] On similar lines Karpovich[3] states that "waste products (may be) a result of disturbances of digestion or because of poor ventilation (leading) to inhalation of noxious gases" that may circulate in blood. That is to say 'fatigue substances', as waste products of activity, present themselves in the organism either due to unusually heavy work or if the task performance conditions are abnormal.[4] Under normal conditions of task performance the presence of 'waste products' as the agent of fatigue of output decrement appears to be unreliable. Dolley[5] conducted a number of experiments by transfusing the blood of a fatigued animal in one instance, and by the injection of artificial fatigue substances such as lactic acid, sarcolactic acid and monopotassium phosphate in another instance, into normal dogs. Regarding their role he says "there is abundant evidence on the physiological side from experiments here recorded to support the anatomical proof ... in the work of the cell ... in the first place their effect in general was transitory (and) in the second place, the findings give a strong impression that waste products, such as sarcolactic acid and monopotassium phosphate,

[1] Otani p. 276.

[2] Thorpe p. 55.

[3] Karpovich p. 238.

[4] Robinson (1934) says that one of the "explanations of true exhaustion psychoses (is) the possibility of an accumulation of fatigue products that act as intoxicating agents" (p. 625).

[5] Dolley p. 36 ff.

are by no means highly efficient in producing anatomical depression ... it is this contrast which strengthens the impression that the waste products are a minor factor".[6] Presumably in view of this fact "muscle physiologists are placing much less reliance than formerly on the idea that fatigue is the result of accumulation of waste products".[7] Moreover the formation of waste products is to some extent dependent "on the inadequacy of oxygen supply to the muscles during their activity"[8] and so an effective supply of oxygen may help in maintenance of performance output.

Weston[9] also observed that "the presence of toxic substances" would destroy the stimulating effect of acetylcholine and thus limit the performance output. Although the release of acetylcholine in the nerve endings as a hormone is generally accepted, its stimulating action is inferred by external administration of enzymes, thus limiting its role only to pharmocological actions. The action of acetylcholine as a hormonal stimulant has not been conclusively demonstrated and is still a subject of interesting controversy.[1] So the limitation of performance output due either to the inhibitory action of fatigue substances or to an inhibition of the stimulating action of acetylcholine, is at least during moderate work, difficult to defend.

Experiments on waste products

The accumulation of lactic acid and the formation of carbon dioxide as a result of continued task performance has also been the subject of a number of experimental investigations. Attempts at an exact determination of oxygen debt as an index of the presence of lactic acid and carbon dioxide in the organism during task performance involves practical difficulties.[2] During progressive task performance increased oxygen consumption "may partly

[6] Dolley pp. 51–52.

[7] Thorpe p. 55.

[8] Karpovich p. 238. The importance of oxygen supply in delaying the onset of 'fatigue' through the conversion of 'fatigue substances' is well illustrated in experiments involving muscular effort in the presence of varying amounts of oxygen (Noltie p. 85 ff., Hill (1929) p. 100 ff., (1924) p. 438 ff., (1925) p. 84 ff., (1925 a) p. 155 ff.).

[9] Weston p. 122.

[1] Feldberg (1957) p. 507, Brazier (1953) p. 59 f.

[2] Eskildsen p. 177.

be due to the increasing anaerobical conditions and partly due to other circumstances induced at that high speed".[3] When the performance rate is high involving a comparatively quick and unknown amount of oxygen uptake, it may be "more or less impossible to fix the exact point when the oxygen uptake is adequate"[4] and experimentally "great errors may be introduced".[5] Henry's[6] experimental study of relative oxygen debt to different grades of metabolic work loads is an interesting contribution in this direction. He found "at light work loads the relation between debt magnitude and metabolic cost was essentially linear up to 6 cal/minute . . . at heavier loads the size of debt showed a relative increase"[7] depending upon an excess formation of lactic acid. It means that "extra lactic acid formation does not occur except in severe work".[8] Erickson,[9] however, reported slightly larger oxygen debt for very light loads. But in his recording technique he used the pre-exercise resting level as a base line for recordings of oxygen debt for the light loads instead of the post-starting exercise level used for the heavy loads and thus showed negligible excess oxygen debt. The absence of excess lactic acid formation during the performance of light work loads, however, does not necessarily mean that no oxygen debt is involved. Margaria[1] distinguished two different types of oxygen debt pay-off during the period of post-work oxygen consumption: 1. Alactacid mechanism. 2. Lactacid mechanism. The oxygen debt in the alactacid mechanism "is a true debt in that it represents the oxidative restoration of energy in payment for energy that was released during the proceeding work".[2] Such oxygen debt payment does not result from any "lag in the circulatory or other adjustments to the early phase of exercise",[3] but is rather "the expression of an oxidative process in which the energy liberated is spent in re-

[3] Christensen (1950 a) p. 253.
[4] Ibid. p. 251.
[5] Ibid. p. 253.
[6] Henry (1951) p. 435 f., (1950) p. 481 f.
[7] Ibid. (1951) p. 437.
[8] Margaria p. 697.
[9] Erickson p. 400 f.
[1] Margaria ibid.
[2] Henry (1951) p. 435, Hill (1940) p. 225 f., (1940 a) p. 465 f.
[3] Henry ibid.

paying the amount of energy set free anaerobically during the muscular contraction".[4] It means that at light work loads there is a maintenance of equilibrium between the formation of lactic acid and the oxidation of the substrate, the dynamics of which result in a steady state of oxygen intake.[5] It would appear that such a state is a possibility in the normal course of task performance. In other words "up to a considerable rate of work, not exceeding two thirds of the maximum aerobic rate of work"[6] or work corresponding to "metabolic work loads upto 5–6 cal/minute",[7] "no lactic acid excess appears in the blood, and presumably in the muscles".[8] At heavier metabolic work loads than 5–6 cal/minute or when the work becomes severe lactic acid accumulates. Under the circumstances the lactacid mechanism may be "considered more like a mechanism of emergency"[9] and therefore it "would not play any important part in muscular contraction except in very strenous exercise, probably in connection with the anaerobic conditions in which the exercise is performed".[1] In support of these considerations there are a number of experimental findings in such easy and moderate exercises as step-test,[2] cycle-ergometer test and running in tread-mill test[3] etc., in which "lactic acid determinations ... failed to show any accumulation of acid in the blood after recovery from a series of such exercises performed at appropriate intervals"[4] and in which there was also "absence of retention of carbon dioxide during the recovery process".[5] The extensive experiments of Douglas[6] are typical in this connection. They determined temperature, lactic

[4] Margaria pp. 708–709.

[5] Eskildsen p. 178.

[6] Margaria p. 698, see also fig. 2. p. 694.

[7] Henry (1951) p. 435, (1950) p. 484 f.

[8] Margaria ibid. According to Gemill "light muscular exercise does not change the blood sugar level (omitting of course) the psychological effect of emotion" (p. 42).

[9] Margaria ibid.

[1] Ibid. p. 713, cf. Christensen (1950) p. 249 f., Dill (1936 a) p. 419.

[2] Berg p. 607 ff.

[3] Best (1929) p. 131 ff.

[4] Ibid. p. 144.

[5] Ibid.

[6] Douglas (1951) p. 211. (Only the highest and lowest values are cited from the series of recordings.)

acid, carbon dioxide and respiratory quotient in an uninterrupted 10 mile walk at the rate of 4 m.p.h. in one subject and 3½ m.p.h. in another.

Effect of a 10 mile walk on the lactic acid concentration in the blood. (Mg/100 ml.)

		Subjects: Craig	Koch
	Rest before walk.	8.5	10.0
During walk-every two miles	highest	9.1	11.4
	lowest	7.6	8.4
Rest after walk-every halv hour.	highest	9.4	11.2
	lowest	8.4	8.7

Carbon dioxide and oxygen consumption: (for Craig) *(See p. 221)*

		Respiratory exchange. ml. min. Co_2	O_2	R. Q.
	Rest before walk.	223	272	0.82
During walk.	highest	1305	1500	0.87
	lowest	1243	1441	0.86
Rest after walk.	highest	227	285	0.80
	lowest	223	282	0.79

The respiratory quotient (i.e. the ratio between Co_2 and O_2) taken as the index of carbon dioxide production to oxygen consumption throughout, i.e. during rest before walk, during walk itself and during rest after walk, varies between 0.87 and 0.79, i.e. somewhat below unity, which proves that the metabolism is going on rather normally in all these cases.[7] As "oxygen is brought into the cells fast enough to reoxidize ... little or no lactic acid is produced",[8] and carbon dioxide is easily removed when the organism reaches a 'steady state'.[9] If necessary addi-

[7] Best (1929) in another experiment on mild exercise found R.Q. to be "lower than unity, while that of moderate exercise tends to approximate to unity" (p. 143, Hill (1925 a) p. 176). In similar experiments Courtice found negligible excess in lactic acid and carbon dioxide and R.Q. was below unity (p. 386 ff.). Cook (1933) p. 446 ff., Owles p. 219 ff., and Bock (1928) p. 137 ff. confirm these results further.

[8] Baldwin p. 425, Brouha (1960) p. 4 f., Hill (1925) p. 126, Lundsgaard (1930) p. 170 ff., (1930 a) p. 77 ff.

[9] Hill (1956) p. 176, (1923) p. 148.

tional oxygen, stored "in the form of muscle oxyhaemoglobin (myoglobin)"[1] in the intracellular region, is available during task performance. Under such conditions mild work can be carried on indefinitely and moderate work for up to 8 hours a day.[2]

Experiments on energy consumption

Energy consumption, the other important factor on which muscular performance output is dependent, has also been the subject of several experiments. They are mostly attempts to investigate the nature of physiological processes like heart rate,[3] blood pressure, body temperature, carbon diovide production, urine content etc.[4] While these investigations are instructive the results are not reliable.[5] The investigations of oxygen consumption[6] and energy expenditure involved in metabolic processes[7] offer a more reliable basis for the understanding of performance output changes. Taylor[8] reported a number of determinations of the mechanical efficiency of boys between 7 and 15 years of age as measured by a bicycle ergometer after cycling for half an hour. The averages for net efficiency, i.e. the "relation between the work done and energy expended in doing the work over and above that required to maintain the body in the 'resting position'",[9] was determined. When the determined performance cost was compared with that of the cost for sitting quietly, it showed a negligible difference. In connection with energy expenditure for moderate tasks characterized by low work intensities, the role of the 'steady state' involved in metabolic processes of effort is interesting. According to Hill[1] the 'steady state' is one "in

[1] Baldwin p. 424, Guyton p. 809, Åstrand (1960 a) p. 453 f.

[2] Wells (1957) p. 54, Hill (1925) p. 136.

[3] Brouha (1954) p. 10 f. The author has reviewed the work of others.

[4] Bock (1928) p. 137 ff.

[5] Berggren states that "pulse determinations can advantageously be used at work of short duration, whereas body temperature determinations can be useful for work of long duration (and) both heart rate, and body temperature can vary independent of metabolic work" (p. 260).

[6] Noltie p. 85 ff.

[7] Carpenter p. 281 ff.

[8] Taylor (1950) p. 566 f.

[9] Ibid. p. 566.

[1] Hill (1923) pp. 148–149.

which the rate of lactic acid production is balanced by the rate of its oxidative removal, and its concentration remains constant in the muscle as long as exercise at that speed is maintained." This 'steady state' was investigated by Bock[2] paying particular attention to metabolic processes that occur inside the body under these circumstances. He concluded that "during continuous muscular exercise a 'steady state' is reachd when the demand for oxygen is adequately met. Such a steady state implies a relatively constant total ventilation,[3] elimination only of carbon dioxide produced in metabolism, steady pulse and respiratory rates and a constant internal environment. These conditions may be associated with an oxygen debt provided it is not cumulative but is chiefly acquired in the period from the beginning of work until the steady state is reached".[4] Thus the role of the steady state appears to be the same in both lactic acid removal and the oxygen consumption during the metabolic processes of energy interchange.

Grading of tasks according to their intensities

Against the background of the implications of steady state that determine the limits of performance output intensities, a consideration of the grading of tasks may be significantly useful in understanding the nature of the task intensities. On the basis of his experimental investigations Wells[5] graded tasks as 'light', 'heavy', and 'severe' according to their respective intensities of load "based on a composite of physiologic criteria including pulse rate, metabolic rate, pulmonary ventilation, respiratory quotient and blood lactates". Such gradation of work in terms of their load intensities is in line with the suggested definition of different grades of work by Christensen[6] and others[7] as corresponding to the respective rates of oxygen consumption or calories per minute

[2] Bock (1928 a) p. 162 ff.

[3] This Would mean a constant P_aO_2 and P_aCo_2. See Evans p. 776 f.

[4] Bock (1928 a) p. 162.

[5] Wells (1957) p. 54.

[6] Christensen (1953) p. 93 ff.

[7] Ivy (1942) p. 569 f., cf. Dill (1936) p. 268 f., Benedict (1913) p. 43. Benedict (1913) has reviewed the metabolic studies of muscular performance of earlier investigators (p. 3 ff.).

energy expenditure.[8] As oxygen consumption is the basic factor in the metabolic processes of energy expenditure the investigators gave particular attention to measuring it. The experimental data indicate that excess oxygen consumption for moderate work is rather small[9] because "recovery (from work) is rapid and practically complete in a few minutes"[1] and "since fuel is rendered available by digestive processes as work proceeds, little call is made on energy reserves".[2] While the performance of 'moderate' tasks involves neither excess energy expenditure nor increase in lactic acid and carbon dioxide, the performance of 'heavy' or 'severe' tasks may involve increased energy expenditure and accumulation of lactic acid and carbon dioxide according to the task intensities.[3] In other words during continued task performance utilization of energy-holding substances and the accumulation of lactic acid and carbon dioxide is relative to the oxidation processes involved in the muscle performance output changes. In the maintenance of dynamic equilibrium, in a period of muscle performance during which these variables are kept in view, the physiological factors that govern the limitations of output may be expressed in terms of the following factors: let 'S' be the store of energy-producing material at the start of a given period of task performance, 'T' the time spent, (A–K) the difference between anabolism and katabolism, the two phases of metabolic activity. If 'E' be the total energy-producing material available at the close of a period of task performance, the net result can be represented by the equation $E = S + T\ (A - K)$. It means that muscular performance, as depending upon the energy available, may result in reduced output, if the muscle consumes the energy-

[8] For a detailed explanation of the rate of energy expenditure in various activities as determined by physiological methods see Guyton p. 827, Passmore p. 805 ff., Karpovich p. 93 ff., Davson p. 109 ff.

[9] Christensen (1953) p. 100, cf. Wyndham p. 927, Benedict (1913) p. 174, (1909) p. 36 ff.

[1] Hill (1925) p. 125, Brouha (1960) p. 17.

[2] Dill (1936) p. 264, (1936 a) p. 421 f., Schubert p. 54. Wigglesworth has shown that glycogen in the form of energy reserve is present in the body and may be called upon in need (p. 157 ff.).

[3] Baldwin observes that "a mass of ... work (makes) it clear that there is strict proportionality between the amount of work done, the heat produced, the tension developed in a muscle, and the quantity of lactic acid formed" (p. 400). See also Brouha (1954) p. 12.

holding substance or oxygen faster than it can be replaced.[4] On the other hand as long as the available store of energy is more than or equal to that of energy-producing potential at any given period of muscular performance, the task performance may be carried on without any possible injury to the organism and hence the organism "can handle the work output as it occurs without running a deficit".[5]

Muscular output in human performance

With this background of the physiological conditions that govern the limitations of muscular output during a period of task performance, we may now turn to a consideration of muscular output investigations in human performance. Experimental investigations in nerve muscle preparations and the more extensive studies using an ergograph have attempted to analyse the nature of muscular output changes during task performance. While the investigations in nerve muscle preparations have been only more or less instructive, the ergographic studies dealing directly with human performance with its genuinely and definitely objective basis demanding comparatively less time "to produce the voluntary fatigue curve"[6] have been advantageous and extensively useful in the investigation of performance output changes. Output curves representing such ergographic work give us a reasonable and adequate picture of output changes in task processes. However, the same thing cannot be said with equal certainty about the nature of output changes involved in more complex tasks like tapping, rowing etc., where one or more muscle groups may be involved. These complex tasks contain more than one item during task performance unlike ergographic work which involves performance of small movements that give rise to a simple kind of behaviour where the single response "is taken out of its setting and produced under exactly determined and constant conditions".[7] Under the circumstances in ergographic work the subject

[4] Brouha (1954) p. 12.

[5] Woodworth (1955) p. 799, Spaeth p. 41. In his ergographic studies involving contractions with light load and with very brief rest pauses Manzer found "anabolic factors completely counteracting the katabolic; the work curve is therefore, a horizontal line" (p. 80).

[6] Schwab (1951) p. 133.

[7] Bartlett (1958) p. 13.

is provided with a definite standard and rate of performance in the execution of his task. Any departure from the set standard and rate of performance can easily be detected, as the subject may resist tendencies to let the level of efficiency fall off until the occurrence of the drop in output can no longer protect him against final and complete decrement. On the other hand in complex tasks like tapping etc., the subject has a much less definite basis for judging his performance output. His efficiency may slip off by a required amount without meeting any great subjective resistence. In the light of these complexities it may appear that ergographic studies of output have little direct bearing on the study of human performance output involving some amount of skill.[8] While this is true to some extent, the task processes involved in ergographic work could be controlled to a degree which is advantageous in offering a definite basis and clue to the analysis and explanation of the physiological and psychological factors underlying the performance of skilled tasks.

In experimental ergographic studies simple muscles or a limited group of muscles in human subjects are exercised with a given weight and the contractions so induced either by voluntary effort or by electrical stimulation are recorded.[9] A close analysis of such studies reveals that performance output is recorded under three heads or classified into three grades of load, namely heavy moderate and rather light,[1] on similar lines to the grading of metabolic work loads into three types discussed above.[2] With the recorded output, output curves for the three respective grades of load could be traced (figure 1).[3] In the case of the first and second

[8] Ibid.

[9] Some investigators, e.g. Franz, have substituted springs of varied length for different grades of weights so that the smallest variations in output may be detected (p. 353 f.).

Hemphill has shown that an ergograph may be used to some extent as an instrument to investigate the clinical aspects of pain and fatigue tolerance in depressed and psycho-neurotic patients (p. 434 ff.).

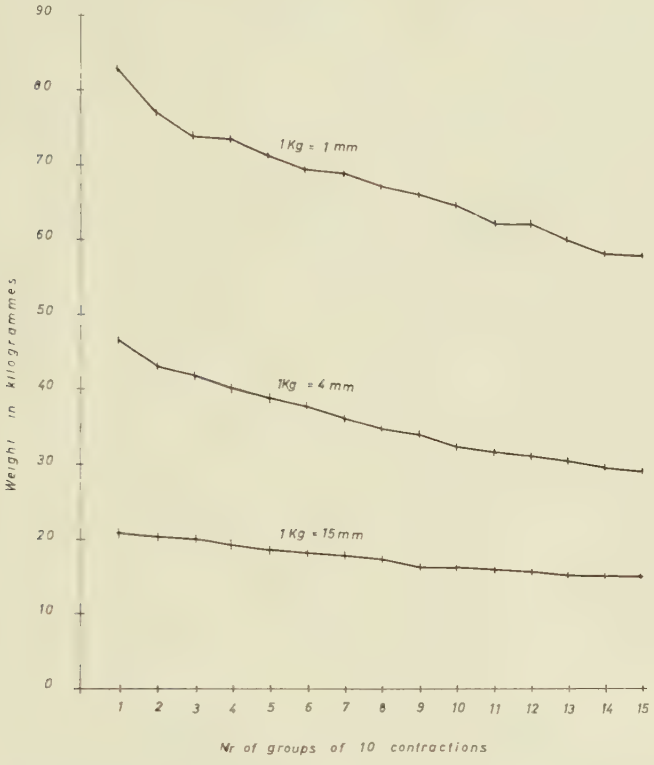
[1] Spaeth p. 24.

[2] See page 37.

[3] The output curves for the three respective grades of load are well illustrated by Franz p. 356. In a similar manner Mosso (1890) p. 94 ff., (1890 a) p. 123 ff., (1892) p. 91 ff., and Iteyko p. 178 ff., offer output curves for heavy

Fig. 1.

Adapted from Franz, S. I, p. 356 (for tables see p. 358).



Tensions overcome with three different kinds of springs (loads). Abscissae denote number of groups of 10 contractions. Ordinates denote amount of tension overcome.

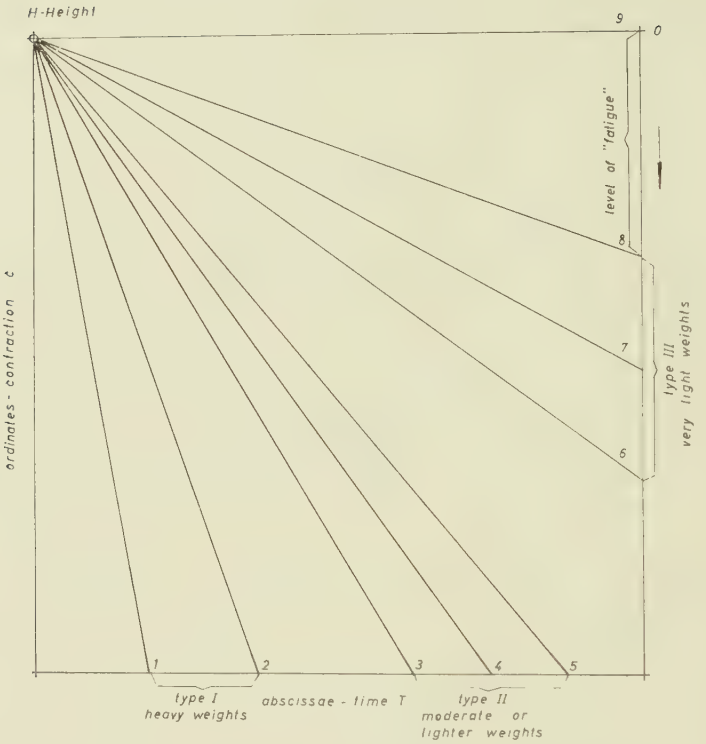
grades of load it may be observed that there is a gradual but appreciable fall in muscle contraction throughout the output curve with a corresponding fall in performance output. But in the third grade of load while the initial output is reduced to some extent due to the diminshing muscle contraction, the output curve soon

loads, Fletcher (1902) p. 490 ff., Budington p. 158 ff., and Lee (1906) p. 14 ff., for moderate loads, and Hough p. 249 ff. for light loads.

Further the output curves of Scripture p. 228 ff., Maggiora (1890) p. 193 ff., (1890 a) p. 187 ff., Lombard (1890) p. 24 ff. (Fig. I–VIII), (1892) p. 58 (curves I–IV), Binet p. 178 ff., Welsch (1898) p. 289 ff., Reid (1929) p. 18 ff., Viteles p. 442 f., and Whitehead (1938 a) p. B ff., may be classified on the lines indicated.

Fig. 2.

Adapted from Spaeth, p. 24.



(A diagrammatic representation of the three types of "fatigue" curves observed in several experimental investigations of muscular output. A careful analysis of "fatigue" curves shows that these curves belong either to type I, II or III.)

reaches an almost constant level beyond which the reduction in output no longer occurs.

For an analytical understanding of the nature and scope of the relationship of the output curves to the three grades of load, a diagrammatic representation of output curves classified by Spaeth[4] may be relevant and of particular importance to our present discussion (figure 2). The output curves for heavy weights are as types 1 and 2, for moderate weights as 3, 4 and 5 and for light weights as 6, 7 and 8. A quick glance through the series

[4] Spaeth p. 24.

of output curves (2 to 9 in the figure) reveals that the curves gradually become asymptotic. If the weights to be exercised in the ergograph are made still lighter we may obviously expect an almost uniform output curve.[5] Manzer[6] reported in one of his experiments that his subjects showed a tendency towards diminishing output during the successive periods of task performance. The experimental subjects, however, were different on different days and some of them had no previous practice. There is also some difference in the experimental apparatus used by the subjects, a factor which can have contributed to the fall in output curve for some of them. Hough[7] on the other hand obtained strikingly uniform output curves from the contractions of the second and third phalanges of the middle finger and the results were constant throughout. In these experimental results the manifestation of a slight initial fall in output followed by an almost uniform output curve may be because the physiological functions get adapted to the new performance situation in view of the fact that there is, comparatively, "less displacement from the resting equilibrium necessary for adjustment".[8] Under the circumstances a muscle or muscle group "need not experience fatigue ... if the rate of work and the load of work are rightly adapted to the working capacity of the body".[9]

The importance of spacing performance

Although a suitable load intensity and a degree of physiological adjustment in the new performance situation would aid the maintenance of performance output, progressive continuity of task performance may cause pressure and strain in the organism. During continued task performance, when the output is

[5] Robinson (1934) p. 587, Lombard (1892) p. 55.

[6] Manzer p. 75.

[7] Hough p. 249, 253. Reid (1929) further confirms the result (p. 21). See also curves on p. 31.

[8] Brouha (1945) p. 142.

[9] Christensen (1953) p. 93, Forbes (1934) p. 174. Yoakum p. 3.

In a recent extensive review and analysis of ergodynamics and muscle physiology concerning fatigue appearing during human muscular work, Scherrer (1960) observes that "fatigue appears only if the imposed power is higher than ... the critical power at which the muscle may maintain its activity during a long time". p. 491. Cf. Dorpat p. 639.

controlled either by static effort or phasic movement at constant speed or constant load, there is a progressive increase in the activity of the muscle. That is to say there is an increasing contraction in the maintenance of output.[1] As the task performance continues, "apart from the increased participation of the muscles which are primarily involved, muscles which are not directly helpful in the particular movement start contracting ... thus throwing extra strain on other muscles".[2] These conditions give rise to increasing development of "purposeless movements"[3] due "to a disturbance of coordination owing to antagonists being to a large extent contracted at the same time".[4] On the other hand continued performance involves conditions where each "phase of contraction runs into the next, so that the muscle is never able to relax completely".[5] As a result there is a progressive "decrease in number of functioning muscle fibres in the motor units during contraction".[6] Thus, during continued task performance the stage is set for deterioration in the muscle processes with its corresponding influence on output as "the activity may cease to be smooth".[7]

Therefore during continued task performance it would appear necessary, in the interests of smooth and efficient working of the muscle processes, that the muscles be exerted "at suitably spaced intervals in different forms of exercise".[8] Introduction of rest

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[1] Knowlton p. 649 f.

[2] Darcus (1953) p. 61.

[3] Ibid.

[4] Lundervold (1951) p. 113.

[5] Darcus ibid. p. 60, cf. Lundervold (1951) p. III f.

[6] Lindquist p. 55. Scherrer's (1959) E. M. G. studies in the human being indicated "a synchronization of motor units ... appearing during every prolonged and intense activity of muscle" (p. 157, ibid. (1957) p. 100 ff., Buchthal (1959) p. 85 f.) which may cause "fatigue" (Buchthal (1950) p. 429 f.). Lindquist however states that "increased synchronization does not necessarily imply ... any abnormal motor neuron activity" (p. 58).

[7] Darcus ibid.

[8] Ibid. p. 64, Dorpat p. 639. Müller states that in order to prevent the occurrence of 'fatigue' the intensity of working rate and the length of the compensating rest pauses must be so adjusted as to give 5 gross over all rates of energy expenditure of not more than 5 cal/min. which he calls "Endurance Limit" (EL) (p. 206, cf. Lehman p. 49 ff. Åstrand's (1960 a) findings indicate that the allotted rest pauses in industry to avoid over-

pauses, better still variation in task (load) performance, offer opportunities for alternate movements during the contraction processes. "There is a delicately controlled reciprocation between the contractions of the primary movers and antagonists. In between alternate bursts of activity of each group of muscles there are varying periods of relaxation (depending) on the speed and load of the movement".[9] The intervening periods of relaxation check the repetitive tendency by reducing its frequency, while at the same time they bring about "a partial restoration to a higher equilibrium level"[1] of the organism. On the other hand alternate movements made possible by rest pauses or by variation of tasks (load) shift the load of movement to alternate muscles, and so by "spreading the load"[2] the static effort could be reduced "by allowing the same movement to be produced by different muscle groups".[3] In this way during continued task performance "unloading of the workers "may have entirely different physiological effects dependent on the duration of work and rest periods" (p. 453).

Brouha (1960) experimentally demonstrated "the fallacy of utilizing fixed rest allowances in industrial operations" and says "the physiological measurements of the worker's reactions are essential to determine the frequency and duration of rest periods". P. 65.

[9] Darcus (1953) p. 60, cf. Lundervold (1951) p. 112, (1951 a) p. 33 ff., Böje p. 17.

[1] Forbes (1934) p. 172, cf. Davis (1932) p. 352 ff.

Pointing out the importance of the restoring function of muscular exercise, Delorme (1945) states that it may be attained by "developing muscle power ... founded on the principle of high-resistence and low-repetition of exercise, whereas the generally accepted principle is low-resistance and high repetitive exercise ... the fatigue that results ... is not due to so much to overcoming resistance, as to the sheer number of repetitions" (p. 645).

According to Darling the ability of the organism to maintain a close internal equilibrium or "effective homeostasis is a characteristic of fitness" (p. 141).

[2] Osgood (1953) p. 341.

[3] Darcus (1953) p. 66, cf. Lundervold (1951 a) p. 35 f.

In a recent investigation Åstrand (1960) observes that "by introducing rest pauses of a certain duration in relation to work time, one can often modify the physiological strain of a given load so that it becomes tolerable" (p. 84). Even in heavy work like lumbering Lundgren has shown that five trained lumber workers of ages ranging from 26 to 55 years "did not produce any signs of overstrain or any other unfavourable bodily symptoms (when) the working periods (were separated) by sufficiently frequent short rest pauses as well as by meal periods ... to attain a moderate and uniform work intensity by spreading the effort over a fairly long total time" (p. 322).

necessary body movements can also be reduced by designing the control"[4] of movement and so "effective fatigue is reduced".[5] At the same time "maximum work can be obtained only by a variable load, which at every length during the contraction is exactly equal to the maximum tension the muscle can exert at that length".[6] The task performance could then be smoothly and efficiently carried on, giving rise to a fairly uniform output curve.[7]

While varied moderate tasks are suitable[8] for smooth and efficient performance, their continuance provides training[9] for the

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[4] Darcus ibid.

[5] Osgood ibid., cf. Mcdougall (1909) p. 262.

[6] Hill (1913) p. 467. Åstrand's (1960) recent investigations showed "the higher the relative work load is, the more difficult it will be for the different regulating mechanisms of the body to maintain the normal state of equilibrium or to restore a disturbed equilibrium" (p. 79).

[7] In his unpublished study of output curves obtained in the course of many days with rest pauses of varying length of 5, 15, and 30 second series, Yochelson "found that after a first and marked diminution the subject early made an adjustment which allowed him to continue almost indefinitely at a fairly constant production level". Cited from Robinson (1934) pp. 584–585.

[8] Christensen's (1950) experimental results with reference to "the consequences (of) professional work and ... performances ... support strongly (the theory that) short spells of severe work ... have an efficiency only half or less (than half) of that aerobical work ... In many cases it may be substituted by aerobical work by lowering the intensity of work, by suitable working tools that increase the way of load and decrease the tension" (pp. 249–50). It may also be noted that in strenous exercise the extra oxygen available is rather small, of the order 0.3l/min. (Wyndham p. 934).

Christensen's (1960) experimental findings indicate that "mechanical efficiency is ... the same or practically the same, whether the work is performed continuously for one hour with an easy load or discontinuously with heavier loads" (p. 444). Åstrand (1960 a) further confirms this (p. 452).

[9] Lenman (1959) states that "unfortunately little is known about ... the physiological changes which exercise produces in nerve and muscle (p. 191). However, Åstrand's (1960 a) results illustrate the fact that suitably paced work can induce "a high training effect ... on respiration and circulation (which) is of interest not only for the training of sportsmen but also for rehabilitation of patients during the convalescent period" (p. 452).

Hemingway (1958) talks of two main types of training. I. "improvement of the physiological capabilities of the individual (which) enables him to perform a given task with less encroachment on his reserves or with greater efficiency. 2. Exploiting the potentialities of the body ... the growth of (its)

organism by way of concurrent opportunities for its development and improvement "by allowing the muscles to act to their best advantage".[1] Under these circumstances the involved physiological processes on the one hand tend to prevent the local 'fatigue'[2] of the organ by increasing the capacity of the physiological mechanisms for comparatively greater oxygen consumption[3] and in-

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wisdom" as judged by excellence of performance, by skill, endurance or strength (p. 897).

Asmussen (1949) states that both static performance involving isometric contraction and dynamic performance involving isotonic contraction contribute to muscle development. As dynamic training offers opportunities for controlling the load and knowledge of results in the range of movement, improvement seems to be more immediate and rapid than in static performance in which there appear to be fewer such opportunities (p. 20 f., cf. Petersen p. 412, Rasch p. 33 f). It may be that there are difficulties in acquiring the technique of maximum isometric contraction in static training in order to achieve advantages of muscle development. However, Ionescu suggests that static training should not be used therapeutically (p. 83 f.).

[1] Darcus (1953) p. 63. Through experimental tests and measurements in physical capacity of 400 Danish school boys between 7 and 17 years of age Asmussen (1955) pointed out "that an increasing ability to mobilize and coordinate the muscles of the body is the reason for the rapidly increasing physical capability in school boys" (p. 603).

Darling showed the relationship of 'unfitness' associated with illness to physical training as indicated by "the concept that rapid convalescence and successful physical training are closely related" (p. 145). Also according to Lenman (1959) "patients with motor weakness due to either primary muscular disease or to disuse of the central nervous system" (p. 194), which "would be analogous to that obtained in a fatigued muscle" (Lenman (1959 a) p. 309), may be corrected by being subjected to treatment and recovery through active exercise (Lenman (1959) p. 192 ff., cf. Leont'ev p. 116 ff., Delorme (1948) p. 267 ff., Sharrad p. 78, Darcus (1955) p. 333 f., Holmgren p. 444 f., Mead p. 459 f.). This however "may deteriorate with rest ... due in part to disuse: in part to an increase in stiffness" (Lenman (1959) p. 194).

[2] According to Åstrand (1958) "the local blood flow through the working skeletal muscle ... might be insufficient, for some reason or other (and may cause) local muscle fatigue" (p. 163, ibid. (1952) p. 143 f, Barcroft p. 408 f., Slonim p. 403, Dill (1936 a) p. 424).

[3] Darling p. 143. Robinson (1941) observed in training nonathletes "for running during a period of 26 weeks ... an average increase of 16 % in the maximal oxygen consumption during exhausting work" (p. 168 f., ibid. (1941 a) p. 428).

Knehr observed in a "training regime of middle distance running over a period of 6 months ... in exhausting work there was an increased capacity

creased blood flow through the working muscle,[4] and on the other hand effect "changes in structure, in strength, and in endurance"[5] involved in the physical capacity[6] of the organism

for supplying oxygen to tissues and greater utilization of anaerobic energy reserves" (p. 155).

[4] Sjöstrand's (1935) experiments demonstrate that under the influence of bodily exercise in "running animals ... the amount of perpheral blood is increased not only in the musculature functioning directly but also in other muscles" (p. 97, cf. Riley p. 582, Linderholm p. 67, Karvonen p. 897 and Bock (1928) p. 159 who offer interesting experiments in this direction.

[5] Karpovich p. 33, cf. Darcus (1953) p. 64, Zinovieff p. 131, Åstrand (1958 a) p. 81, Steinhus p. 104 ff.

[6] Christensen (1960 a) p. 463, Clarke (1958) summarized a number of studies on exercise showing its relation to physical fitness and related "physical fitness in turn to the organic, mental, and social attributes of the individual". He says further that "we should have the strength and stamina to carry on the duties of the day without undue fatigue and with an ample reserve to enjoy leisure and to meet unusual situations and emergencies: we should realize in an adequate measure our capacity to physical activity as well as for mental accomplishments unhampered by efficiency-destroying fatigue" (p. 465) cf. columbine p. 507 ff.

Attempts at an ideal test to determine the physical capacity of the organism have not been successful because of the failure to meet the condition "that it be definitely strenous and involve a minimum of skill" (Darling p. 142). However, Ryhming using pulse and oxygen uptake determinations (p. 236 ff.), Wahlund utilizing pulse and respiratory rates (p. 74, cf. Bengtsson (1957) p. 17 f., (1957 a) p. 2 ff., (1956) p. 372 f.), and Asmussen (1958) p. 70 f., Åstrand (1955) p. 922 f., using comparative capacity for extra maximum oxygen uptake have all shown these to be suitable indicators of working capacity. The recent work of Andersen (1959) on respiratory and circulatory determinations as an indiex of physical fitness is only limited to selected clinical subjects and so is not representative (p. 51 ff., ibid. (1960) p. 92 f.), and according to Bengtsson (1956 a) "estimates of working capacity based on the recovery pulse were only of very limited value" (p. 108).

It appears that the effects of increased improvement in the primary muscles during a period of training in task performance is also found to increase the improvement of the antagonists in strength and power, although there is no experimental evidence of any activity in the antagonists during the contraction processes of the primary muscles (Darcus (1955) p. 335, Lenman (1959) p. 191). According to Hellbrand (1947) such effects in the antagonists are due to an involuntary spread through cross education (p. 84 f.). Darcus (1955) using light loads where "fatigue was minimal" suggests that it is unnecessary to exercise muscles to a great degree in order to get transfer effects (p. 335), and he also states that such improvement due to "training has some permanent or semi-permanent effect on the neuromuscular system" (p. 334, cf. Morris p. 425 f., Abramsson p. 153 ff.). However the nature of the processes

which indirectly help to achieve increased performance output.[7]

The nature of "slöjd" performance

Against the background of the nature of muscle processes, discussed in relation to human performance output variations during 'moderate' tasks involving rest intervals or variations in task (load), it would be relevant to consider the nature of "slöjd" performance. The 'load' involved in a two hour 'slöjd' performance is either light or as moderate as is adaptable to the working conditions[8] and purpose of the school. "Slöjd" tasks, being neuromuscular by nature the operational processes, are characterized by rhythm and variety inevitably causing alternation of effort between different muscles or muscle groups. At the same time 'slöjd' performance is not perfectly continous "but interspersed with short pauses or blocks which increase in length and frequency in proportion to the length and difficulty of the task (and which have) recuperative function".[9] Physiologically the rhythm of alternate contraction and relaxation processes involved in

involved in achieving improvement in "power and endurance" by continued moderate exercise "is a matter of speculation" (Darcus (1953) p. 64). Hellebrandt's (1958) "observation of the motor behaviour of both normal and disabled subjects (indicates) that the imperfectly understood central nervous system changes associated with motor learning play a more important role in programs designed to increase muscle performance than generally appreciated". P. 282 cf. Leont'ev p. 102 ff., 146 ff.

[7] Brouha (1945) p. 143, cf. Dill (1933) p. 61. Benedict (1913) p. 162. Robinson (1941) in course of training non-athlets for running found "consistent improvement in timed races on the tracks (with) an improvement of 8 % in efficiency in running" p. 168. Ibid. (1941 a) p. 428.

Knehr found "in a training regime for middle distance running ... an increase in efficiency of grade walking" p. 155.

[8] With reference to modern industrial work Müller observes that "the tools, the machines, the whole industrial equipment are designed by engineers, who are never schooled to solve the problem of selective adaptation in man. So, in industrial work it is necessary to ensure that recovery keeps pace with fatigue" (p. 206).

[9] Ivy (1942) p. 571. From a therapeutic point of view Delorme (1945) classifies tasks "according to the quality developed in the exercised muscle-namely, power, endurance, speed and coordination" (p. 645); "several different ways of doing the same exercise ... will prevent the patient's losing interest from monotony ... the greater the variety of exercises, the greater the patient's interest" (ibid. p. 666).

'slöjd' performance may act in such a way that it "helps the heart in circulating blood (which) rinses out waste products and brings fresh food-stuffs and oxygen and thus hastens recovery".[1] Continuance of task performance tends ao increase "the blood flow through (the) muscle during contraction and relaxation, (as a result of which) the better (is) the recovery from fatigue".[2] The nature of this performance probably provides "a way in which (the subject) can check his performance from time to time and satisfy himself that he is keeping up the standard with which he started, (and a way in which) his bodily mechanism can go on working just as well as ever for a very long time indeed"[3] maintaining the level of performance output.[4] On the other hand the task processes with their inherent and natural rest intervals may simplify the task adaptation in the new performance situation so that "the pulse keeps a constant rate, proportional to the energy rate".[5] Under the conditions of the "physiological steady state (where) work and rest periods are adequately organized"[6] the performance intensity tends to remain in terms of industrial physiology "below the EL".[7] Therefore the output level can be

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[1] Müller p. 205. Åstrand's (1960 a) findings show that in paced tasks "lactic acid during short periods of rest is eliminated almost at the same rate" (p. 453, cf. Lehman p. 49).

[2] Müller ibid. The author observes that "the life-long endurance of cardiac and respiratory muscles shows that relaxation time itself can be sufficient for a complete recovery in uninterrupted rhythmic muscular activity" (pp. 205–206, cf. Baetjer p. 465 f.).

[3] Bartlett (1951 b) p. 57.

[4] Robinson (1926) making performance heterogeneous, obtained constant work curves (p. 439 ff.). Bedford's study of various output curves indicated that "where there was a variety of work and the operation was of a rhythmic nature, a rapid fall in output was avoided and the work-curve remained steady with a tendency to rise throughout the day" (p. 244, cf. Whitehead (1938) p. 33 f., (1938 a) p. B_5 ff.).

[5] Müller p. 208.

[6] Brouha (1954) p. 19.

[7] Müller p. 210. With the aid of recovery pulse sum (RPS), i e. "pulse sum above resting level from the end of work till the end of recovery" (p. 209), Müller has shown that 'rest pause' activities remain well under the endurance limit, thus causing no "fatigue" (p. 210 ff.).

Åstrand's (1960 a) findings indicate that "work with short periods (of rest pauses) was subjectively felt to be relatively light: and the subject experienced no fatigue after one hour" (p. 451).

maintained throughout the performance period[8] and a considerable amount of experimental data supports this view.[9]

Conclusion

These considerations explain the fact that the muscle factors involved in the physiology of a period of task performance do not effect any appreciable change in output during continuous work under normal conditions. In the absence of real muscular changes[1] the phenomena of a decrease in output can be related to the defence mechanism, which prevents the organism from possible overwork.[2] The mechanisms involved in the feed-back system or the phenomena of "equilibrium is subject, of course, to many modifications and motivations".[3] But before these important factors claim our attention, it will be necessary to consider the role of neural factors involved in performance output changes.

[8] Manzer experimentally inducing muscle contractions by light loads with successive rest pauses showed that the output "curve is horizontal and the working time is indefinite in length" (pp. 80–81). Müller states that "organization of the necessary pauses leads to a greater output, despite shortening of the official working hours" (p. 214).

[9] Carmichael's (1951) extensive experiments in 'fatigue' tests on differential discrimination, range finding, eye-hand tracking, crossing letters, and complex reaction time showed that "the subjects for most part did as effective work in brief samples of activity at the end of 74 hours, for example, as when fresh and well rested" (p. 94, cf. Weber (1950) p. 263).

[1] According to Wenger "except in sports or extreme conditions such as combat, true physiological fatigue is seldom encountered" (p. 380).

[2] Baetjer p. 467, Woodworth (1955) p. 802, cf. Rosenbluth who has shown "the independence of transmission fatigue and contraction fatigue", and states that "the drop in the response to stimulation ... is due to transmission fatigue and not to contraction fatigue" (pp. 152–153). See also figs. 50 and 51 on pp. 153–154.

Siddal, in an experimental analysis of deterioration in continuous tracking, found that "neither the subjects nor the writers in trial runs experienced symptoms of such gross muscular fatigue as would be necessary to account for the deviation in tracking" (p. 165).

[3] Schwab (1951) p. 134, cf. Osgood (1953) p. 341.

CHAPTER III

THE PHYSIOLOGICAL BACKGROUND: NEURAL FACTORS INVOLVED IN VARIATIONS OF OUTPUT

The neurons at work

The output variations discussed in connection with the muscle processes of task performance "involve not only the muscles concerned but also the neural units involved in maintaining the activity".[1] During mental task processes of performance the neural units involved have been considered to be primarily subjected to fatigue.[2] The neural unit involved in the mental output variations is the nerve cell "with all its processes"[3] known as a

[1] Ivy (1942) p. 571.

[2] Mosso observed in his classic ergographic experiment that a fatigued finger could respond by electrical stimulation of the motor nerve meaning "that the fatigue has occurred higher up in the nervous system" (Woodworth (1955) p. 802) cf. Beach (1960) p. 66 f., 146 ff.

Lion states that "the fatigue produced by strain of the extrinsic ocular muscles is ... a fatigue in the central nervous system, and not of the extrinsic eye muscles as such" (p. 389, cf. Rosenblueth p. 150, Brozek p. 259).

[3] Gardner (1958) p. 28, Hebb (1958) p. 67. According to Bodian (1952) the "neuron is the ... seat of complex chemical processes which may concern not only impulse conduction but also its ability to maintain itself as a specialized cell" (p. I, cf. Gardner ibid. p. 91, Brink (1957) p. 193 f., Davson (1951) p. 376).

The nerve impulse is an electro-chemical reaction deriving the energy sources from the neuron itself (Gardner ibid. p. 95 f., Hebb ibid. p. 90, Loewenstein (1959 b) p. 367 f.). The nature of this electro-chemical reaction is "still not established beyond dispute" (Brazier (1953) p. 14). However it is generally understood that the electrical effect or the 'action potential' in the nerve results from a depolarization of the resting membrane. There is a short circuit during the depolarized state (Castillo (1956) p. 123 f., Hebb ibid. p. 91), and "this potential difference is determined primarily by the distribution of

neuron,[4] and billions of such neurons go to make up the nervous

Na, K, and Cl ions between the inside and outside of the cell" (Brink (1957) p. 193, Hodgkin (1959) p. 426 f., Kuffler (1958) p. 514 f., Hodgkin (1951) p. 401, Walker (1947) p. 22). During the processes of ion exchange "the membrane potential reverses sign, and its total swing is several times greater" than at the beginning (Castillo (1956) p. 123, Nachmansohn (1950 a) p. 79, (1950 b) p. 591). For a detailed description of ionic movements involved in nerve activity see Huxley (1959 b) p. 221 ff., Guyton p. 26 ff.).

The membrane potential difference is however considered to be an inadequate explanation of the rise of 'action potential' (Asano p. 15), and it is postulated that "the rise of the action potential is brought about by rapid entry of Na into the fibre" (Castillo (1956) p. 125, Hodgkin (1955) p. 54 f., (1952) p. 544, Brazier (1953) p. 53, Nastuk (1950) p. 72, Rothenberg p. 109 ff.), and "it has been suggested that there is in the membrane a 'sodium pump' ... to maintain Na at a high concentration outside the fiber" (Gardner (1958) p. 99). However "nothing is known of the nature of the sodium pump, if it exists, and the rate and nature of metabolic processes remains to be determined" (Gardner (1958) p. 99, Tasaki p. 119, Hebb (1958) p. 91 f., Muralt p. 128, Keynes p. 171).

Conway, in a recent study of some features of the Na pump action says "that the pumping out of Na ions could be expected to be a fundamental endowment of the cell, and hence to be observable over a wide range of cellular species" (p. 33).

An alternative suggestion with regard to the determination of potential difference is that the electrical state of an axon surface is primarily related to oxidative processes in the membrane (Lorente de' No (1947) p. 145), (1947 a) p. 189), perhaps through the ATP oxidation processes (Shanes p. II f.). However Brink (1957) "suggests a close coupling between the rate of oxidative processes and electro-chemical state of the axons" during the depolarized state (p. 193, cf. Therman p. 109 f., Lorente de' No (1948) p. 57 ff., (1947 a) p. 165 ff.).

[4] "To avoid confusion between the cell body and the whole cell unit (including its fibres) the latter is usually spoken of as the neuron" (Brazier (1953) p. I). The neurons exist in diverse forms, depending primarily upon "the magnitude of the sources of stimuli or number of synaptic contacts which converge upon them (and secondarily upon) the magnitude of the fields of innervation of their axons or as yet poorly understood functions of their greatly variable dendrites" (Bodian (1952) p. I).

Magoun (1958) observes "within the individual neuron, graded response mechanisms have been identified at either end of the classically conducted nerves" (p. 115).

Hebb (1958) observes that although the dendrite and the axon of the neuron conduct according to their property, "direct excitation of the cell-body is an evolutionary development which permits more efficient conduction" (p. 88), and "that cell-body (fires on) the all-or-none principle" like the axon (ibid. p. 90).

system. A nerve is a bundle of nerve fibres that "conduct nerve impulses between non-nervous tissues and the central nervous system, and between various parts of the central nervous system".[5] Neurons thus "came to be regarded as discrete anatomical units, with no protoplasmic continuity or intervening material between them[6] and probably the neuronal 'processes' "make possible the functional connections (between them) to form conduction pathways".[7] These functional connections which make intercommunication possible between neurons for conduction of impulses across a gap are termed synapses.[8] It may now be apparent that mental performance output changes primarily involve the neurons as sources of energy transformation and interchange, either because of stimulus excitation or during "conduction of impulses occurring over chains of such neurones".[9]

Attempts to understand the functional changes in the neuron through direct observation[1] either by induced stimuli or electrical stimulation is rather complex and Grow[2] stated that "what actually takes place in the nerve cell when a stimulus is received and a response to that stimulus is induced is still in the realm of the

[5] Gardner (1958) p. 28.

[6] David p. 58.

[7] Gardner (1958) p. 72, cf. Bodian (1942) p. 162.

[8] Cajal established "that the functional connections between ... neurons, are effected by close contacts and not by continuity in a syncytial net-work (and) Sherrington gave the name 'synapse' to these functional connections that are made by close contact between nerve cells" (Eccles (1957) p. I, (1959) p. 247, Grundfest (1959) p. 148, David p. 58, Brazier (1953) p. 10).

Palay (1958) in his direct histological observation has established the evidence for the synapse. He says "the connection between nerve cells (is) discontinuous (and) also ... there is no intervening third element ... between the two neuronal components of the synapse" thus confirming Cajal's theory (p. 285). Synapses like neurons are complex and exhibit great variations in their features "such as surface area of contact, form, distance, structure of the postsynaptic membrane, and other aspects of microstructure (which) affect the electric response time characteristics, threshold and many other features may be greatly modified" (Nachmansohn (1955) p. 43, cf. Bodian (1952) p. 8 ff., Robertson p. 384 ff.).

[9] Gardner (1958) p. 91, Davson (1951) p. 376 f.

[1] Hodge stimulating the ganglion cells of frogs and cats observed decrement in the size of their cells (p. 481 ff.).

[2] Grow p. 108.

conjectural". With the advance of neurophysiology recent histological observations of nerve cells reveal no changes in neurons during their functional activity.[3]

Neurons and oxygen supply

A number of investigations into the quantitative changes of metabolism[4] have been attempted in order to understand the relationship of output changes to metabolic measures of mental effort. Such measures imply that mental output variations may be due to the activity of the neurons that comprise the central nervous system. Sokoloff[5] however, found it difficult to conceive metabolic equivalents of mental effort "in the sense that muscular work, either skeletal or cardiac, requires additional amounts of oxygen". But according to Mcdougall[6] activity in the central nervous system "does essentially and always involve liberation of energy, transformation of energy from the potential to the active form, and a consumption or using up of stores of potential energy". The metabolic measures in accordance with this view are roughly changes in blood-supply,[7] respiration and pulse rate[8] and especially oxygen consumption and the related by-products of lactic acid and CO_2.[9] Diverse and extensive investigations in this respect are no doubt instructive and good points of departure. Gerard[1] for example, reported increased uptake of oxygen during electrical stimulation of nerves. He observed that this increase was due to "the local influence of the applied currents and is

[3] The recent investigations of Delgado (1959) revealed that fatiguability of the brain due to prolonged stimulation manifested itself in different degrees in different areas of the brain, slow in some areas, quick in others and "no fatigue (in another area) after 72 hours of continuous stimulation" (p. 474, cf. DeFlorida p. 228 f.). However Delgado observes that "in no case did prolonged stimulation of the brain cause visible histological damage" (ibid.).

[4] Dodge (1917) p. 91 f., (1913) p. 10 ff.

[5] Sokoloff (1955 a) p. 1106.

[6] Mcdougall (1909) p. 258.

[7] Causey p. 143 ff., cf. Myerson (1930) p. 389 ff.

[8] Huxtable p. 32 ff.

[9] Benedict (1933) p. 42 ff. Geildreich's (p. 7 ff.) and Huxtable's investigations cover a wide range of metabolic measures like temperature, relative blood pressure, pulse rate, respiration, palmar skin resistance etc. (p. 35 ff.).

[1] Gerard (1932) p. 519 ff. He also reported a number of other such experiments (ibid. cf. Gerard (1927) p. 402 f.).

quite independent of the natural conducted process in nerve fibres".[2] There may be a number of complex undetermined variables that enter into natural conducted impulse in response to a stimulus. Apart from these observations Gerard's[3] results shed no light on mental performance output changes and the changes resulting from neural activity. However, oxygen consumption as the prime factor in the transformation and utilization of energy by the individual neuron during the metabolic processes, of mental effort[4] has as we shall now see, been the subject of extensive investigations.

A failure to maintain the metabolic equilibrium during continued mental effort may result in output changes due to a "failure to strike a balance between the processes responsible for the conduction and transmission of the nerve impulses and the supply of oxygen necessary to maintain the chemical processes concerned in the maintenance of the nervous mechanism".[5] During mental performance output changes involving the metabolic processes of oxygen consumption and energy interchange,[6] heat is liberated.[7] The heat liberation in the nerve under stimulation "appears abruptly (and) falls off abruptly at the end of stimulation, and in the case of a short period of activity may amount to as little as 3 percent of the whole"[8] heat. During electrical activity of the nerve, according to Hodgkin,[9] experi-

[2] Ibid. (1932) p. 522.

[3] Gerard ibid.

[4] Hemingway (1953) p. 69 f.

[5] Ibid. p. 71.

[6] The transformation and utilization of energy by neurons is dependent on the adenylic acid system that was discussed for the muscle activity processes (see above p. 29). However "the chemical reactions by which ATP makes it energy available for the performance of (mental) functions" are made less clear (Guyton p. 811, cf. Gardner (1958) p. 350 f.).

[7] Brink (1957) p. 195, cf. Brazier (1953) p. 14.

[8] Bard p. 940.

[9] Hodgkin (1951) p. 396, cf. Davson (1951) p. 427. Hill (1932) has shown that "when a nerve is stimulated not once only but many times in succession the heat per impulse is less" (p. 23, cf. Gerard (1927 a) p. 291 f., Forbes (1929) p. 119). The heat per impulse is several times greater at lower than at higher temperatures (Gerard (1932) pp. 517–518).

Heat production in the nerve analogous to that in the muscle, under stimulation takes place in two phases, the initial one during the process of depolari-

ments indicated that the "additional heat production associated with activity was not large".

With regard to the oxygen consumption[1] of neurons under direct stimulation Brink[2] states that "a sequence of processes associated with excitation and response can take place in the membrane in absence of oxygen metabolism" because of the presence of "an energy reserve, indepently of an oxidizing one".[3] This means that neural activity is possible without oxidative metabolism. But of course there may be an uptake of oxygen during metabolic processes of mental effort. It is true that Gerard[4] demonstrated the failure of conduction in the anoxic axon. But his experiment offered evidence merely for the necessity of oxidative metabolism in the absence of an "an oxygen reserve".[5] It showed no extra oxygen consumption by the active axon and "there is no experimental evidence in the literature in support of (the hypothesis that) the extra oxygen consumption following (mental) activity is ... essential for maintenance of the conduction mechanism in active axons".[6] On the contrary there is abun-

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zation that accompanies conduction, and the delayed one following conduction when the response is over and the nerve re-establishes its resting polarized state (Bard p. 940). Hill (1932) in his extensive studies established "that the passage of a nerve impulse is accompanied by a heat production of approximately 10^{-7} small cal. per. gm. of nerve fibre" (cited from Brazier (1953) p. 15). During the initial phase "only a small fraction of heat is given off (and) the major part of the heat produced is clearly related to the restorative process since it is maximal during the recovery period" (ibid.). With reference to this phenomenon Bard states that "the heat production of the nerve is ... different from that of the muscle in that the ratio of initial heat: delayed heat is much less than 1 : 25 ... the whole of the delayed heat, not merely a fraction of it, occurs whether oxygen is present or not" (p. 940).

[1] For a review of the literature on oxygen consumption and respiratory exchange during mental work see Page p. 388 ff.

[2] Brink (1957) p. 205.

[3] Gerard (1932) p. 533, cf. Brink (1957) p. 191 f.

[4] Gerard (1932) p. 494 ff.

[5] Ibid. p. 500.

[6] Brink (1952) p. 61. It is interesting to note that "at constant frequency, the average quantity of oxygen (uptake) per volley is larger the shorter the train of impulses" (ibid. p. 59, Gerard (1932) p. 551). According to Brink (1952) "such relations merely reflect the kinetic characteristics of the chemical reaction system that supplies the chemical energy and are not to be understood in terms of energy requirements of active axons" (p. 59).

dant experimental evidence that the oxygen supply for the resting metabolism of neurons is adequate for all their needs.[7]

It is however apparent that oxygen consumption during mental work is a function of the neurons[8] involved in the brain as a whole. Larrabee's[9] experiments on oxygen consumption in animal brains showed "that the differences ... in oxygen lack, are not clear-cut", but that the oxygen consumption is constant throughout. There is a probability that the components of mental work "may be accompanied by a redistribution in the pattern of activity throughout"[1] the brain and "areas with increased functional and metabolic activity could then be counterbalanced by areas of reduced activity so that the total cerebral oxygen consumption is unchanged".[2] Or it may be that biochemical changes occurring during metabolic processes "may be sharply localized to areas within the brain so small as not to produce an effect in over-all measurements".[3] Further, although the nervous system is primarily involved in mental effort, "the brain is neither a pump nor a motor and its current counter-parts seem to be instruments

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[7] Brink (1952) cites a number of experiments in support of the view that the nerve could still conduct impulses when an increase in oxygen uptake above the resting level of the nerve is abolished (p. 60 f., cf. Bronk (1951) p. 20, Gerard (1950) p. 116 f.). Gerard (1932) in an extensive study of the metabolism of nerve states that "in contrast to muscle, which increases its resting metabolism several thousand-fold during maximal activity, the resting rates are hardly double in nerve" (p. 551).

Doty in an independent experiment on oxygen uptake by neurons "found conduction can continue for hours in nerves with surely a third and probably over half the resting oxygen consumption (and) since the normal increase on activity is only 30 % of the resting rate in these nerves, the spare resting metabolism could easily cover this amount, since both resting and active metabolic energies derive their substrate from a common pool of energy sources" (p. 467).

[8] Peares p. 64. Sokoloff (1955 a) stated that no experiment is reported on the estimation of oxygen consumption involving "the fraction of the total brain tissues which consists of functional units or neurons and (that he is) even less cognizant of the fraction of the neurons involved in the various functions which comprise conscious mental activity" (p. 1107).

[9] Larrabee p. 256.

[1] sokoloff (1955 a) p. 1106.

[2] Ibid. pp. 1106–1107, cf. Himwich p. 119 f., Freeman (1935 a) p. 63.

[3] Kety (1957) p. 233.

of computation and communication".[4] Thus during prolonged mental effort "although a defective power supply will produce dysfunction",[5] the task processes themselves are not "always correlated with the power used".[6] If conscious and cognitive processes of mental activity are considered to be associated with the cerebral power used, Mangold[7] showed that in natural sleep, a state of relative unconsciousness unassociated with pathologic processes,[8] cerebral oxygen consumption is unchanged from that of the normal waking state involving conscious processes.[9]

However, in spite of an energy reserve and "the considerable safety factor normally present"[1] in the neuron, a period of continous mental work may result in "interference with the ... metabolic processes which can reduce the production of energy and inhibit the synthesis of substances necessary for the conduction of impulses, for the maintenance of polarization of nerve membrane, and for the repolarization after conduction".[2] But such organic alterations of cerebral metabolism that may cause disturbance in cerebral function due to mental effort may arise only through "an overwhelming interference with cerebral metabolic activity".[3] Such possibilities of undue interference with cerebral metabolism through normal mental effort may be safely ruled out because the "alterations in the functional activity of the

[4] Ibid.

[5] Ibid.

[6] Ibid.

[7] Mangold p. 1099, cf. Shapot p. 262, Sokoloff (1955 a) p. 1106 ff.

[8] Lassen established "that the cerebral oxygen uptake is subnormal only in acute and chronic cerebral disorders characterized by distinct signs of mental hyperfunction, depression of consciousness in acute disorders, and loss of intellectual faculties in chronic disorders" (pp. 232–233).

[9] Lassen's findings, that "in normal man, not given to pharmacological agents, the cerebral oxygen uptake is remarkably constant (and) cerebral oxygen consumption is unchanged during sleep and during physical and intellectual effort" (p. 232), confirm Mangold's (ibid.) conclusions.

[1] Gerard (1950) p. 116.

[2] Gardner (1958) p. 350, cf. Gerard (1932) p. 534. Shapot's experimental determinations in relation to the functional capacity of the central nervous system and brain metabolism revealed that "in so far as the specific functional activity of the nerve cells is dependent on complex protein structures, it is reasonable to suppose that the inhibition of protein synthesis should result in a reduced capacity for further nervous activity" p. 260).

[3] Kety (1957) p. 233.

brain are found to be unassociated with detectable changes in oxygen consumption"[4] except in some abnormal and pathological states of reduced consciousness.[5] Therefore the oxygen needs of resting metabolism appear to be adequate for normal mental work.

There are a number of other investigations that attempt to establish a relationship between oxidative increase and mental performance output during a period of hard mental exercise. Lennox[6] reported increased oxygen content of internal jugular venous blood during reading and mental work involving arithmetical problems in 10 out of his 15 subjects. The author failed, however, to measure the arterial oxygen content, so his findings are unreliable. Moreover Sokoloff's[7] extensive investigations into cerebral circulation at rest and during the mental work of solving arithmetical problems fail to confirm Lennox's[8] findings. He states that except for a "small but statistically significant rise in pulse rate and mean arterial blood pressure ... mental arithmetic (work) was not accompanied by any change in ... cerebral blood flow, cerebral oxygen consumption, cerebral vascular resistance and cerebral respiratory quotient".[9] There was also no change "in blood constituents such as oxygen and carbon dioxide concentrations, carbon dioxide tension, pH, or arterial hemoglobin concentration".[1] However, the subjects showed considerable anxiety in preparing for the start of the experimental task and during the task period with regard to the outcome of their task. These emotions obviously influenced the task results. Under the controlled experimental conditions and in the absence of any other

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[4] Ibid. According to the author "a number of drugs which produce definite changes in mental state have been found not to produce a generalized effect upon oxidative metabolism of the brain" ibid.).

[5] Kety's (1950) experimental investigations showed that the reduction in cerebral oxygen consumption in pathological states of reduced consciousness that reflect a block in the maintenance mechanisms is due to failure to maintain the structural and functional integrity of the brain (p. 212 ff.).

[6] Lennox p. 730, cf. Allwood p. 112 and Abramson (1940) p. 552, present experiments of some interest in this connection.

[7] Sokoloff (1955 a) p. 1107.

[8] Lennox ibid.

[9] Sokoloff (1955 a) pp. 1107–1108.

[1] Ibid. p. 1108.

factor, Sokoloff[2] ascribes the slight increase in pulse rate and mean arterial blood pressure to the "anxiety" evidenced in the experimental subjects during the mental task period. Further Sokoloff's[3] recordings of the subjects to get independent evidence of mental concentration while attending to the solution of the arithmetical problems showed "lack of correlation between the degree of mental activity ... and the rate of oxygen consumption of the brain as a whole".[4] Rounds[5] in another experiment reported increased oxygen consumption during mental effort. But he failed to take into consideration the extra muscular factors involved during mental effort and the motivational factors involved due to the novelty of the task, requiring dynamic adjustment under the new situation which might influence the increased indices of oxygen consumption. The experiment was conducted on only one subject and there are several irregularities in conducting the experiment. Benedict and Benedict[6] extensively investigated silent mental arithmetic calculations lasting for over an hour involving the least amount of muscular effort after controlling different intervening variables. It was concluded "that with intense, sustained mental effort, such as in multiplication ... the increase in heat production as a result of intense mental best index of energy transformations, is such as to suggest that the increase in heat production as a result of intense mental effort of this type can hardly be of the order of more than 3 or 4 percent".[7] Three years later the same authors repeated another

[2] Ibid. p. 1107. Lassen's experimental results show that "with the possible exception of severe anxiety states no significant changes of cerebral oxygen uptake have been reported in a varity of conditions studied" (p. 232).

Huxtable in his extensive investigations into metabolic studies in mental work obtained a slightly increased respiration and pulse rate which he ascribed "to the excitement of initiating the experiment" (p. 37), and a slightly increased metabolic rate which he ascribed to "nervous tension stimulated by competition" (ibid. p. 33). Gillespie obtained in an experiment increased pulse rate and blood pressure during mental activity and suggested that the "emotional factor ... (was) the cause of the difference" (p. 431), which confirms the previous results.

[3] Sokoloff p. 1105.

[4] Ibid. p. 1108.

[5] Rounds pp. 77–78.

[6] Benedict (1930) p. 438 ff.

[7] Ibid p. 443.

series of experiments on the metabolic equivalents of mental effort using trained subjects doing arithmetical calculations. They concluded that the metabolic increase during an hour of severe mental activity is rather insignificant.[8] Moreover the small increase of 3 or 4 % in oxygen consumption and in heat production obtained is "accounted for by the increased muscular activity accompanying the increased ventilation of the lungs and the increased heart rate".[9] The later experimental findings of Huxtable[1] support these findings, and Tiffin[2] stated that "physiological changes that occur in mental work are quite small ... and to late have been of limited practical value as criteria of the effects of mental work". Therefore Benedict[3] suggests that "this increase (in oxygen consumption can be) in no wise ascribed to a proportionate increase in the oxidative activity of the cells of the brain". Moreover several other extensive and consistent experimental investigations conclusively point out that a period of prolonged, intense and sustained mental activity has "an insignificant effect upon the general level of vital activity".[4] Under these circumstances mental performance output may be maintained at a fairly constant level thoughout the performance period.

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[8] Ibid. (1933) p. 83, cf. Best (1955) p. 621.

[9] Benedict (1933) p. 81.

[1] Huxtable p. 38.

[2] Tiffin pp. 435–436, cf. Harmon p. 77.

[3] Benedict (1933) p. 83. The author has reviewed in detail earlier investigations (p. 7 ff.). Benedict (1909) in an earlier investigation obtained a 6 % increase in oxygen consumption (p. 98 ff.). Similarly Becker (p. 147 ff.) and Rosenblum (p. 219 ff.) show slightly increased but different values for oxygen consumption during mental effort. Such increases are due to the effect of the novelty of the experimental task and the consequent adjustment to it and also to the excess muscular activity of the subjects during the experiment. Bendict (1909) ascribed the increased oxygen consumption to such factors p. 98 f. thus confirming the later results.

[4] Benedict (1933) p. 82, (1930) p. 443, Waller (1920) p. CVII. Goldstein argued that since the brain tissue is small compared to the body tissue, its activities cannot therefore influence the total energy to a great extent (p. 53)

Robinson (1934) points out that responses involved in the thinking processes are so small and varied that they are unlikely to lead to mental fatigue (p. 573 f.).

The other important factor closely associated with the oxygen consumption during the metabolic processes of mental effort is the formation of waste products of metabolism, Co_2, and lactic acid. With regard to waste products it was pointed out during the discussion of muscle output changes that experimental investigations have not precisely formulated the nature of the substance comprising these products.[5] Gerard[6] stated that "during anoxia 'toxic' metabolic products accumulate and are directly responsible for block" in the nerve. In normal mental activity involving cerebral functions, however, waste or toxic products may play no role.

The role of lactic acid and Co_2 in mental output changes may be primarily explained in terms of the resting nerve metabolism as "it participates in reactions of the oxidative metabolism".[7] A certain concentration of lactic acid and Co_2 is always present when the nerve is at rest[8] and is used for its resting metabolism.[9] But this does not mean that a lactic acid production cycle is involved in mental output variations. Through his direct studies Gerard[1] has shown that "the rate and amount of its production are entirely unaffected by activity". With adequate oxygen penetration, a glycolysis process that gives rise to an increased production of lactic acid and carbon dioxide of course "appears to be excluded for activity under any conditions".[2] Myerson[3] failed to confirm the production of brain lactic acid and carbon dioxide

[5] See pp. 30–32.

[6] Gerard (1932) p. 536 f.

[7] Lorente de' No (1947) p. 189.

[8] Schmitt p. 342.

[9] The presence of "5 % of Co_2 (helps) the enzymatic mechanism of nerve (to) utilize stores of metabolic energy more readily or more effectively" so that the nerve is able "to withstand without failure the effect of an (increasing) applied cathodal current" (Lorente de' No (1947) p. 167, cf. Lassen p. 201 f.).

[1] Gerard (1932) p. 532.

[2] Ibid. p. 502, cf. Cook (1933) p. 450. Gerard (ibid.) states "that lactic acid formation in nerve can be prevented by oxidation of non-carbohydrates" (p. 496).

[3] Myerson (1931) p. 377, (1930) p. 405 f., Winterstein p. 210 ff., cf. Kennersley (1929) p. 1135 f., (1930) p. 711 and p. 721, and Schmitt p. 348.

in his experiments on human subjects. In view of the unavoidable presence of different elements during mental performance involved in the energy mobilization of neurons, Richter[4] undertook to study in a series of experiments the effect of muscular activity on brain lactic acid production. He found "no evidence of any rise in the brain lactic acid".[5] However, he found an increased level of brain lactic acid due to the emotional excitement involved in increased mental activity. The increased brain lactic acid due to emotional excitement "is associated with increased glycolytic activity involving a break down of high energy phosphorous compounds ... which occur in functional activity in muscle".[6] The rise in brain lactic acid due to emotional disturbance "is a transient effect, followed by a rapid return to normal when the stimulus is discontinued".[7] Under these circumstances mental performance output would remain unaffected by chemical products like lactic acid and carbon dioxide.

Experiments on prolonged mental work

A number of other experiments have been attempted to determine the effects of prolonged mental work of from 2 to 12 hours upon output variations. They are generally tests in multiplication, addition, tests of attention and memory etc., carried out among children and adults to measure their efficiency in doing mental tasks before and after a period of hard mental exercise.[8] Chapman[9] reported an experiment with 20 subjects consisting of 16 minute continuous addition with 30 second intervals on seven successive occasions. He observed rapid early loss of output followed by maintenance of a fairly constant level. The subject "very rapidly settles down to a normal rate at which he can work for long periods".[1] But Painter[2] failed to find such an

[4] Richter (1948) p. 78 f.

[5] Ibid. p. 78.

[6] Ibid. pp. 78–79, cf. Richter (1949) p. 253 f., Dawson (1950 a) p. 266.

[7] Richter (1948) p. 79.

[8] Thorndike (1900) has made a number of such experiments (p. 469 ff., 550 ff.), and has also reviewed similar work by a number of other investigators (ibid. (1926) p. 20 ff.).

[9] Chapman (1916) p. 259 f.

[1] Ibid. p. 260.

[2] Painter p. 25 ff.

initial drop followed by a maintainable level in arithmetical experiments. Instead there was a growing irregularity in the working rate, culminating in the failure of the subject to continue the task. The experiment was conducted on only one subject and so it seems "absurd to generalize concerning the course of mental work under extreme fatigue".[3] Other experiments which report similar output variations during continual mental work failed to take into consideration the practice effect that influences the output.[4] And others show output variations due to the season or the time of day,[5] or to environmental conditions like the home and the school or to hygienic conditions.[6] Most of these extensive studies do indicate slight mental output variations. However the mental activity itself neither appeared to slacken, nor was less 'effective', due to prolonged work.[7] Summarizing his own classic experimental investigations, along with those of other investigators, into output changes during continuous mental work, Thorndike[8] concluded that "the most important fact about the curve of efficiency of a function under two hours or less continuous maximal exercise is that it is, when freed from daily eccentricities, so near a straight line and so near a horizontal line. The work grows ... much more unbearable, but not much less effective". These considerations suggest that output variations resulting from a period of continued mental activity are not due to "any passive failure ... of its controlling neural paths".[9] Dodge[1] regarded it "as improbable that any of the mental work decrements so commonly treated as mental

[3] Ibid. p. 30.

[4] Dawson (1924) p. 369.

[5] Steiner (1929 a) p. 88, cf. (1929) p. 449 ff., Winch p. 315 ff.

[6] Heck p. 34.

[7] Huxtable p. 20 ff., Thorndike (1900) p. 481.

[8] Thorndike (1926) p. 69. In his extensive studies on continuous reading Carmichael (1951) came to the same conclusion (p. 94, ibid. (1949) p. 692 ff.).

[9] Woodworth (1955) p. 802.

[1] Dodge (1917) p. 94. Wenger states that "'mental fatigue' which follows ... a bout of studying calculus is (not) directly and primarily dependent upon the fatigue of individual nerve fibres in the brain ... (this) is almost certainly not the case ... Nervous fatigue is not the controlling factor" (p. 34). Carmichael's (1947) extensive experiments in reading "during ... a long period of time (did not cause) any cost to organism" (p. 362).

fatigue are ever simply conditioned by true fatigue processes in nerve tissue. Conversely real fatigue may not appear as a decrement at all".

Conclusion

The absence of neural and muscular elements as influencing agencies of performance output decrement does not, however, rule out the general problem of output variations present during a period of continuous work. Before we consider the psychological factors involved in these performance output changes, it would however be relevant to study the mechanisms in the interaction of nerve and muscle elements.

CHAPTER IV

THE INTERACTION OF NERVE AND MUSCLE ELEMENTS

Neuro-muscular junction

During continued task performance neuromuscular elements are closely involved in the conduction of impulses[1] along the

[1] The transmission of excitation is "qualitatively and quantitatively similar for nerve and skeletal muscle" (Curtis (1950) p. 584). Also "the electric excitation of the axon, and the transmission across the synapse does not differ fundamentally from the propagation of the impulse along the membrane of a single cell" (Castillo (1956) p. 128). The difference if any is "largely because of the anatomical structure" (Brazier (1953) p. 95, Nachmansohn (1950 b) p. 590, Curtis (1950) p. 589).

One of the most common theories of propagation of impulses emphasizes the chemical mediating action of acetylcholine (Ach) (Grundfest (1959) p. 166 ff., Fatt (1959) p. 211 f.). It is suggested that Ach is released during the processes of "the alterations of the active surface membrane during the passage of the impulse" (Nachmansohn (1950 b) p. 546). Its reaction is considered to be independent of ATP breakdown which is connected more with the recovery phase of muscle contraction processes than with conduction of nerve impulses and so may supply the energy necessary for the resynthesis of Ach hydrolyzed during the activity processes (ibid., cf. Brazier (1953) p. 15). Several studies report the observation of the release of Ach, synthesized in a stored form in the motor nerve, at the motor nerve endings (Birks p. 166, Robertson p. 391 f., Castillo (1956) p. 127, Liley p. 664, Katz (1956) p. 212, Bennet p. 57 f., Welsh (1955) p. 98 ff., Palade 335 f., Fatt (1952 a) p. 275). Thus the "junctional region ... is subject to a bombardment by minute quantities of Ach which are released spontaneously ... from the nerve endings (resulting) in appearance of 'miniature e. p. p.', small local depolarizations of the fibre membrane" (Katz (1956) p. 211, Castillo (1956) p. 127 f., (1955) p. 180, (1955 a) p. 410, (1954) p. 601 f., Fatt (1954) p. 681 f., (1952) p. 127, (1951) p. 368). The appearance of e. p. p. is not directly related to the "transfer of ions, or the flow of current, from the nerve endings, simply because there are not enough ions inside the nerve endings to generate the

neuromuscular synapse,[2] the junctional point of contact between the neurons and the muscles. As it is obvious that a neuron or "a nerve could be kept active over long periods without fatiguing",[3] the repetitive stimulation of neurons under junctional contact during continuous task performance is more apt to result in "a local fatigue of nerve-endings in the spot ... stimulated"[4] rather than in the participating neurons. Therefore it is

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required current" (Fatt (1952 a) p. 277). But in generating e. p. p., Ach primarily causes characteristic alterations of the membrane permeability (Douglas 1960 p. 512) which bring about "the ionic conductance of the endplate membrane and give rise to an intense local current flow" (Castillo (1956) p. 166, (1955 a) p. 410, Nastuk (1953) p. 102, (1959) p. 317 ff., Nachmansohn (1955) p. 35 f., (1950 a) p. 80). As the release of Ach and its reaction, is an "intracellular process" (Nachmansohn (1955) p. 43, (1950 b) p. 583, (1950 a) p. 83 ff.), "a direct spread of action current may take place" (Castillo (1956) p. 129) through "a large amplification ... actually produced by the chemical transmitter mechanism at the neuromuscular junction" (Brock p. 455). Ach thus provides "an additional conducting path ... at the end-plate". Castillo (1955 a) p. 408 ff., (1955) p. 180. Nachmansohn (1955) p. 34.

The role of Ach as the agent in the transmission of impulses across the synapse, though accepted by some (Bullock 1947, p. 19), is however unsatisfactory for a complete explanation of the theory (Nachmansohn (1955) p. 43, Granit (1955) p. 25). The precise nature of the transmitting action across the synapse is still obscure (Gray (1959) p. 139 f., Castillo (1956) p. 166 f., Brock p. 455). Eccles (1947) failed to observe the transmission of impulses at the synapse by Ach mediation (p. 204, (1959 a) 67, (1936) p. 369, Feldberg (1945) p. 637). Some consider Ach reactions to be purely of pharmacological value (Feldberg (1957) p. 503).

[2] The "junctional region between nerve and muscle represents a neuromuscular synapse, having properties similar to those of synaptic junctions in the central nervous system" (Gardner (1958) p. 141, Eccles (1959) p. 247, couteaux p. 338, Hagiwara p. 175 f.). Although electrophysiological studies in conduction are well advanced "the factors governing events at synaptic junctions are not known with certainty" Gardner (1958) p. 112, Otani p. 274, Gerard (1932) p. 546 f.).

[3] Gerard (1932) p. 470.

[4] Sherrington (1906) p. 218. According to Guyton repeated stimulation during prolonged performance "is likely to diminish the quantity of Ach released with each impulse, therefore it is said that very rapid stimulation of the endplate fatigues the myoneural junction" (p. 47, Castillo (1956) pp. 148–149, Luco p. 500). Such action of Ach assumed at the *central* synapses (Feldberg 1952 p. 199 f.) is however denied by others (Brazier (1953) p. 88 f., Bradley p. 487).

According to Viteles during prolonged task performance "the contact be-

to the synapse that the incident of fatigue is ascribed[5] as the nerves by themselves are regarded as "relatively indefatiguable".[6]

So the evidence indicates that "fatigue" is in the neuromuscular junction, and in connection with synaptic fatigue Brown[7] pointed out that "neuromuscular block regularly occurs at frequencies of nerve stimulation which are within the physiological range". The presence of blocks that cause "synaptic delay is ... a significant event and not something which can be explained away on the basis of a slowing of conduction",[8] and a good number of experimental investigations support this view.[9]

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tween nerve cell and muscle cell literally becomes fouled, supposedly by products of activity" (p. 452). It is thought that "many abnormal intermediary metabolites and some kinds of inorganic ions are sent into circulating blood from overworked muscular tissue" (Otani p. 276, Lee (1907) p. 178). However the precise nature of these so-called "fatigue substances" is obscure. It is observed that there is "humoral regulation by these substances (and by their action on) central synapses ... (which) presumably ... alter the synaptic membrane towards the state of cathodal depression" (Otani p. 276) which Lorente de' No (1948) ascribes to fatigue (p. 79). Thorpe observes that modern muscle physiologists consider "accumulation of waste products" as an unreliable factor in explaining fatigue. According to him "fatigue phenomena at the motor end-plate and the synapse ... *is* more plausibly regarded as a state of disequilibrium involving a number of factors, including perhaps interference between two or more nervous processes, rather than a simple matter of waste product accumulation" (p. 55).

[5] Guyton p. 521, Sherrington (1906) p. 222, (1904) p. 740, Forbes (1912) p. 122.

[6] Guyton p. 47, Sherrington (1906) p. 223, Gerard (1932) p. 470, Myers (1924) p. 4, Mcdougall (1909) p. 261, Lee (1909) p. 524.

[7] Brown (1949) p. 194. The block at the motor end-plate is never absolute and so does not agree with Merton's (1956) conclusions that the exhaustion of the muscle cells is the only cause of fatigue (p. 220, cf. Merton (1954) p. 564, (1950) p. 527, Naess p. 366). Merton (1957), however, later modified his conclusions and supports Browns (ibid.) findings that fatigue is neuromuscular (p. 135).

[8] Bishop p. 387.

[9] Krnjevic demonstrated that the feature "mainly responsible for failure of neuromuscular propagation ... was block of propagation between the end-plate and the rest of the fibre" (p. 454).

Brazier (1953) stated that "characteristic of the synapse is that it fatigues" (p. 86). According to Hemingway (1953) "fatigue is located particularly at the end-plates of nerve fibre" (p. 70). Wenger located it "at the myo-neural junction rather than in nerve or muscle" (p. 380, Guyton p. 47, Otani p. 275,

Performance output limitations associated with an apparent decrease in contraction can, however, also be due to "cathodal depression", developed in the central synapses resulting in "a block in the transmission of motor impulses".[1] Therefore we have to consider the implications of the central mechanisms in the brain. In this connection Reid's[2] ingenious ergograph experiment is very relevant. In the course of the voluntary lifting of weights in the ergograph the subjects reached a limit when they could no longer lift the weights. At this stage "the flexion muscle involved was stimulated electrically near the motor end-plate of the efferent nerve",[3] and thereby the response to stimulation reappeared and the performance output began to increase.[4] This means that the output limitations have their counterpart located also in a central mechanism as "some form of inhibition".[5] The neuromuscular processes are centrally inregistered and limit the sending of motor impulses to protect the neuro-muscular apparatus from 'overstimulation'.[6] In other words in "the central synapses (which) play the role of safety-valves in the whole sensory-motor system of our bodies",[7] there is a generation of

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Woodworth (1955) p. 802, Dodge (1917) p. 93 ff., Lee (1909) p. 524, (1909 a) p. 388 f., Levy (1901) p. 226 f.).

Carmichael (1947) stated that his extensive studies "seem to confirm the view that the total normal sensory neuromuscular eye mechanism is remarkably resistant to fatigue in an operation such as normal reading" (p. 354). But if the work is sustained for too long without sufficient rest and restoration, the work is beyond the tolerance of cells and a break in the circuit will appear (Briensen p. 288 ff.). However such "functional fatigue either does not occur or is very transient" (Weston p. 119).

A general distinction is made between 'mental' fatigue and nervous or neural fatigue and the latter is characterized by "structural abnormalities in the neuromuscular system ... and disease in nerves (needing) medical or surgical treatment" (Schwab (1953) pp. 143–144, Hebb (1949) p. 211, Forbes (1943) p. 156 f.).

[1] Otani p. 272 ff.

[2] Reid (1929) p. 19 ff.

[3] Osgood (1953) p. 339.

[4] Osgood (1953) offers a clear diagrammatic exposition of the phenomena (ibid.), cf. Grandjean p. 1589 f. See also Otani p. 274 f.

[5] Osgood ibid.

[6] Brazier (1953) p. 86, Davson (1951) p. 440.

[7] Otani p. 276.

inhibition by aid of afferent impulses from the peripheral processes, and this whole feed-back is a "protective cushion, preventing the organism from doing itself actual physical injury".[8]

The refractory phase

A consideration of the phenomenon of the refractory phase may be important as it is associated with the reduction of the original intensity of response[9] or with the inhibition of the response when a constant stimulus incites a continued response. Sherrington[1] demonstrated that the irritability of the scratch reflex in a dog is reduced under prolonged stimulation and that the reduced irritability subsequent to stimulation is the 'refractory phase'. In the refractory period, which has also been demonstrated in nerve and muscle[2] and human reflexes[3]—hence its relevance for our discussion—we come across a "pronounced tendency not to repeat a mental act, requiring a constantly increasing stimulus for producing continued rapid repetitions of the same mental act, and tending to delay their succession with stimuli of the same intensity".[4] This means that during continued task performance refractoriness of nerve limits comparatively the

[8] Osgood ibid. Weiner right describes in detail such mechanisms in animals and men (p. 113 ff.).

[9] Analysing the nature of the electric response of the cortex during continued stimulation Bartley (1933) states that the "results of direct stimulation to an isolated area of the cortex indicate a long refractory period corresponding to the slow rhythm of the spontaneous activity observed" (p. 184).

Verworn has shown that the refractory phase is an elementary phenomenon of "fatigue" (p. 173).

Lorente de' No (1948) considers the reduced response is due to a "cathodal depression" of nerve or relative refractoriness due to a "deficit of Q fraction" i. e. a deficit in the membrane potential during the descending limb of the spike (p. 79).

[1] Sherrington (1906) p. 45 f.

[2] Gotch (1910) p. 256 ff., (1899) p. 410 ff. For the refractory period in skeletal muscle see Brucke (1941) p. 90, (1941 a) p. 470.

[3] Dodge (1913 a) p. 2 ff., (1911) p. 53 ff., Zwardemaker p. 325 ff.

It has been demonstrated that during the period of stimulation the nerve "passes through a stage of complete inexcitability, the absolute refractory period (then) a period of reduced excitability, the relative refractory period" and before returning to its original resting state passes "through a state of hyperexcitability, the supernormal phase" (Davson (1951) p. 406, Brazier (1953) p. 18, Gardner (1958) p. 107, Lucas p. 29 ff., Adrian p. 68 ff).

[4] Dodge (1913 a) pp. 6–7.

number of impulses which may be initiated by repetitive task precsses. "The longer continued and more frequent the stimulation, the more slowly a fibre will recover and, therefore the fewer impulses per second it will carry".[5] Thus the refractory phase as related to the time interval of nerve recovery subsequent to stimulation may to some extent explain the gradual slowing of response during repeated task processes of performance.[6]

The psychological refractory period

A reference to the concept of "psychological refractory period"[7] may be relevant because it has sometimes been explained in terms of the "refractory phase". The psychological refractory period means that during task performance consisting of "a continuous series of stimuli (the) response will appear to oscillate, at some rate of frequency . . . dependent upon a refractory period, during the course of which a normal effector response to a second stimulus cannot be effectively initiated".[8] The reason for this is that the second stimulus arrives at a time when the conducting mechanism is occupied with the previous stimulus[9] and therefore needs to wait or be held in store until the conducting mechanism is cleared to be recharged again.[1] It would therefore follow that

[5] Wenger p. 34, Creed p. 34 f.

[6] Brazier (1953) p. 30 f. Gerard (1932) states that the more intense and frequent the stimulation of nerve "the longer can breakdown be kept ahead of recovery (at) a lower level of equilibration" (p. 542). The absolute refractory period checks the nerve from extreme activation and so "complete fatigue of a nerve, in the sense of inactivity as an end result of activity alone, is ordinarily impossible (which) accounts for the results of the long series of experiments showing the non-fatigability of nerve" (ibid.).

[7] Marill p. 93, Welford (1952) p. 2, Vince (1948) p. 149 f., Hick (1948) p. 40 ff. Craik has elaborated such phenomena in detail (p. 144 ff.), and Welford (1952) has developed the theory to a more complete form as a psychological limit of the rate of response (p. 2 ff.).

[8] Vince (1948) p. 156.

[9] Davis (1959) has shown that "the delays arise as a result of paying attention to the first signal" during repeated task performance (p. 220).

[1] Welford (1952) p. 3. The ineffectiveness of a second stimulus however strong during the refractory period is understood to be due to "line-busy" effect (Brazier (1953) p. 18). According to Hebb (1958) "a cell that is fired at a rapid rate (during repeated performance) begins to have a kind of supply problem" (p. 92). Although Na ions are not completely exhausted during firing, it takes time for refilling of the ion after each firing.

the task processes during prolonged activity are "step like and seriatim rather than diffuse and continuous".[2] The time interval between blocks during task processes is about one R. T. or 0.5 sec.,[3] while that of the refractory period is between 2 and 30 milliseconds depending upon the nature of the fibre.[4] Thus we can say that "'psychological refractoriness' means increased latency".[5] However, the analogy between psychological refractoriness and the refractory phase is rather loose.

Bills[6] nevertheless refers to the refractory phase as a factor explaining mental work decrement in relation to his studies in mental blocking[7] occurring during continued task processes of performance.[8] He says that "a consideration of refractory period in nerve operations, especially the recent findings of Forbes[9]

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[2] Elithorn p. 116, Vince (1949) p. 38 f., Hick (1948) p. 51.

[3] Davis (1956) p. 34, Welford (1952) p. 2, Vince (1948) p. 156.

[4] Wenger p. 28, Brazier (1953) p. 30 f. According to Chusid "a time interval (usually between 0,001 and 0,0005 sec.) is required for an impulse to pass across a synapse in mammalian spinal cord" (p. 66).

[5] Welford (1952) p. 2.

[6] Bills (1931) p. 230.

[7] A number of experimental studies reviewed by Carmichael (1949) show that "the pattern of human fatigue is ... seen to be one of periodic blocks or interruptions in performance of varying frequency and duration rather than continuous decrement as shown in the work curves secured in the study of isolated muscle groups" (p. 695) ibid. (1949 a) p. 445.

[8] Bills (1935) noted that the main cause for blocking is the repeated excitation of the same response mechanism. In accordance with his principle of homogeneity in repeated task processes he observed that the fewer the colours to respond, the more often a response mechanism will be called into play and the greater the blocking (p. 174 ff.). Warren (1937) in his vigilant experiments confirmed these findings (p. 104).

Geildreich's interesting experiments consisted of colour naming (mental work) colour gazing (sensory component), and key board operating (mental component). Having subtracted the scores of sensory and mental components from mental work, he concluded that "the trends of changes in the rate of colour naming and blocking are not due to chance but are due to factors present in the mental work operation and the organisation of the mental worker" (p. 26). He talks about "large blocks or 'block groups' which result from momentarily shifted attention and reduced alertness (and which are) forced by the task pressure to reorient attention to the immediate stimulus" as something different from the "automatic and spontaneous" blocks that are more to do with competition (ibid. p. 27).

[9] Forbes (1929) p. 144.

pointing to the existence of cumulative refractive period, of greater length than the simple phase, suggest that a corresponding recurrent gap in the mental activity ought to occur".[1] And "secondly, as to the interpretation of the neural mechanism involved (in mental blocking), it appears to be related to the neurological phenomenon of refractory phase. Since the refractory period does not follow every response but rather occurs after every group of 20 or so responses, it seems necessary to associate it with cumulative rather than simple refraction".[2] The reported mental 'blocking'[3] consists of periodic gaps[4] or pauses in between responses during continued task processes of performance. These enforced blocks cannot be prevented by the subject in the course of continuous task processes. 'Fatigue' increases the length and frequency of the blocks, qualified by the individual's reaction to task continuity and difficulty. It is also assumed that these blocks are a sort of resting period at frequent intervals during task performance to allow the delicate nervous mechanism involved in mental reactions to recuperate before real impairment may occur.

Of interest in connection with Bill's point of view is that the tendencies to pause in between responses are reported in several repetitive experiments on maze travel by rats[5] and in reaction

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[1] Bills (1931) p. 230.

[2] Ibid. p. 244, Robinson (1926 a) p. 417.

[3] Bills (1931) p. 243 f., (1935) p. 174 f.

[4] Philpott (1932) in a classic study of human output curves came to the conclusion that output curves were non-random and contain periodic rhythms, that the rhythm in grand total curves tends to be constant in phase, and that rhythmic flactuations in output curves show geometric rather than arithmetic progression (p. 101 ff.), thus reinforcing Bills (1931) work (p. 230 ff.). See also Philpott (1950) p. 1 ff., Freeman (1935) p. 151.

[5] A number of maze experiments demonstrated that rats tended to avoid a response just made (Tolman (1925) p. 290 f., Yoshioka p. 257 ff.). A most extensive programme of this nature was worked out by Dennis (1939) and his co-workers and their important findings were that the rats tended to avoid a pathway very recently explored, which they explained by their principle of negative adaptation (p. 305 ff., ibid. (1934) p. 197 ff., Wingfield (1934) p. 135 ff.). However, Dennis provided no hint of the underlying mechanisms involved in the "spontaneous alternation" of the two-choice maze situation.

time experiments[6] where the "avoidance of repetition tendency ... resulted from ... a decrement in the tendency to perform the reaction just performed, which results strictly from the performance of that reaction, rather than from any consequence of its performance".[7] Marill[8] demonstrated that "initiating a response during the early part of another reaction time leads to longer R. T. than initiating this response at a later time". The prolongation of reaction time would seem to be the appearance of the psychological refractory phase related to the mental 'block' that occurs during task processes of performance.

It may also be necessary to mention the output decrement observed in massed practice experiments where "when a response is made, there is a temporary decrease in the tendency to make that response again".[9] Hovland's[1] study of the trials needed for human subjects to learn nonsense syllable lists of different lengths under conditions of massed and distributed practice, and Humphrey's[2] demonstration of conditioned lid reflex response, clearly showed the superiority of distributed practice and that the resultant output was greatly influenced by the time interval between responses. Graham-Gagne[3] showed under restricted imposed conditions of run-away situation, the acquisition of the conditioned operant (locomotor) response was more rapid with longer time intervals between runs. In these massed practice experiments "the most characteristic change under prolonged or

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[6] Woodrow p. 100 ff.

[7] Heathers p. 379.

[8] Marill p. 96. Woodrow reports a similar experiment in increased reaction time when the length of the preparatory interval between stimulus and response was shortened or lengthened beyond a regular favourable interval of about 2 sec. He considered such prolongation in reaction time by unfavourably short or long intervals to be due to attention and recognized it to be innately related to the psychological processes of adjustment and accomodation that are to be found in the refractory phase (pp. 150–151). On similar lines experiments in lifting weights, judging linear magnitudes and hand-writing specimens are reported by Garrett (p. 100 ff).

[9] Singleton p. 171.

[1] Hovland (1940) p. 282 f.

[2] Humphrey p. 380 f.

[3] Graham-Gagne p. 276 f., cf. Gagne (1941) p. 215 f.

repeated stimulation is diminution"[4] in performance output due to the presence of periodic blocks during task processes. Poffenberger,[5] in an experimental study illustrating output decrement, concluded "that the more nearly the work involves the continuous exercise of a single function the more will output of work decrease, and the more varied the functions involved in the work the less will output of work decrease".

Continued task processes in massed practice studies not only involve the recency factor[6] but the frequency factor as well. Robinson[7] demonstrated the causal output decrement due to the presence of these twin factors in homogeneous and continuous task performance. He is of the same opinion as Bills[8] and says that "it is the broad principle of refractoriness of response that gives a basis for interpreting the influence of homogeneity of work upon the magnitude of the work decrement. The fewer the part-activities involved in continuous work the shorter will be the time-intervals between the successive stimulations of each of these activities and, within a given time-range, the more frequent will be those successive stimulations. - - - The degree of refractoriness is a function of both the recency and the frequency with which the activity is called upon to function".[9] It follows that the accumulated output decrement resulting from repeated activity processes is "cumulative and builds up steadily when a series of similar responses is called for".[1] In massed practice tasks therefore, "since relatively homogeneous work involves

[4] Bartley (1951) p. 328.

[5] Poffenberger (1927) p. 296.

[6] Dodge's (1913 a) experiment on wink reflex exemplifies the factor of the isolation of recency which is apparent in the reactions of the organism's early resistance to repetition. As the time interval between stimulation increases there is a gradual increase in the probability and completeness of the second response (p. 6). The same graduation of the refractory phase has been demonstrated by Verworn p. 159 f.

[7] Robinson (1926 a) p. 417. Cf. Dodge (1917), who implied the output decrement due to recency and frequency of response repetition in his first law of fatigue, 'the law of stimulus intensity' (p. 102, cf. Robinson (1926) p. 126 ff., (1934) p. 605 ff.).

[8] Bills ibid.

[9] Robinson (1926 a) p. 417.

[1] Singleton p. 171.

greater recency and frequency of functioning of each of its part-activities than does relatively heterogeneous work, we should expect psychological activities of a homogeneous sort to manifest more refractoriness and, therefore, more decrement than work of a more heterogeneous sort".[2] By spacing the continuous task performance the accumulation of such output decrement may be prevented. Bills[3] for instance demonstrated an almost complete disappearance of periodic 'blocks' from his subject's record by introducing experimental rest pauses of the same length as normally appearing 'blocks' during continued task performance.

While a number of experiments in continuous task performance clearly indicate that the effects of the refractory phase associated with the occurrence of blocks are factors explaining performance output decrement,[4] some consider it to be less important. Its universality is disputed[5] and it is not considered to be "an ultimate explanation"[6] of the occurrence of performance output decrement.

There are a number of investigations which appear to disagree with the view that the refractory phase is the only explanation of the avoidance of repetition involved in the output of work decrement. Lewin[7] reported that some of his subjects, during the performance of homogenous and continuous tasks involving "genuine repetition", reached a point at which there was a tendency to disinclination "to execute the act (response) yet again". Disinclination to continue the task may induce distortions in sense perception. It is difficult to interpret the disinclination to continue the task and the distortions in sense perception as being due to an unusually prolonged refractory phase. Nor can the refractory phase theory be held to account for the well-known

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[2] Robinson ibid. p. 442, (1926) p. 123 ff., (1934) p. 605 ff. The more complicated psychological factors involved in the principle of heterogeneity are considered in chapters 5 and 6.

[3] Bills (1936) p. 344 f., (1935 a) p. 572.

[4] Thorndike (1927) p. 234 f., Luh p. 276 f., Telford p. 7 ff., Dodge (1927) p. 238 f., Davis (1956) p. 36, (1956 a) p. 39.

[5] Elithorn p. 116, Holliday p. 88, Luh p. 279, Thorndike (1927) p. 236.

[6] Telford p. 33.

[7] Lewin (1935) p. 254 f., (1928) p. 144 ff., see also tafel I and II on p. 153 f., (1938) p. 284, (1954) p. 952 ff., (1951) p. 282 ff.

changes in feeling tone that usually accompany disinclination to continue prolonged repetitive work.[8] Robinson[9] does not regard the "refractory theory as the sole explanatory principle", as for instance the "phenomena of partial automatization"[1] need to be explained in other ways. The cortical operations involved in the psychological processes of task performance may not be too rigidly implied to mean that the same neurons are involved in two or more responses to the same stimulus. But there may be, among the structural elements involved in the task processes, a sort of dynamic pattern determined by the relations between the parts of the system and neurons not specifically activated.[2] Further, as already mentioned there is a discrepancy between the time intervals of the refractory phase in the nerve which are rather of brief duration, not longer than 1 milli second[3] and the associated mental blocks causing output decreament which "have an average frequency of about 3 per minute",[4] varying somewhat with different individuals.

Central inhibition and refractory phase

In connection with the discrepancies in the time intervals Creed[5] observed, that "it is possible, under certain conditions, to distinguish between the effects of refractory period and inhibition". But it is in fact rather difficult to understand its role as something unrelated to at least a central inhibition. It is obvious that the reduced excitability of the neuron during the refractory period give rise to "the decline in responsiveness",[6] a state of inhibition associated with the pattern of stimulaton and especially referred to the synapse or "nerve endings in the spot ... stimulated".[7] The delayed response is "a significant event"[8] and "the

[8] Poffenberger (1928) p. 459 f., Arai p. 113 f., Muscio (1921 a) p. 158 f., Thorndike (1926) p. 124, (1917) p. 265 f.

[9] Robinson (1931) p. 240.

[1] Ibid.

[2] Ibid. p. 231.

[3] Sherrington (1906) p. 44.

[4] Bills (1931) p. 243.

[5] Creed p. 35.

[6] Davis (1953) p. 179.

[7] Sherrington (1906) p. 218.

[8] Bishop p. 387.

seat of inhibition appears ... to lie ... in an internuncial mechanism synapse or neuron—between them".[9] The coexisting events of neural refractoriness and inhibition at the seat of synapse is not accidental. According to Purpura[1] inhibitory activity can be related to refractoriness. There is evidence that delays during repeated stimulation may last for a matter of minutes instead of milliseconds.[2] But Forbe's[3] experimental findings point to the existence of a cumulative refractive period of greater length than the simple phase, and it is in this connection that the physiological phenomena of refractory phase can be associated with the occurrence of inhibitory 'blocks' during repeated task pracesses.[4] That is, the pattern of stimulation during repeated task performance "even in a short and rapid tetanus, quickly and greatly prolongs the refractory phase".[5] So it is possible that this prolonged refractory phase can explain the inhibition in central synapses.

Adaptation

The decline in response resulting from continued task performance does not necessarily mean a reduction in the capacity for activity of the organism. Under the conditions of increased frequency of stimulation "the fibre becomes rapidly adapted to the new conditions"[6] and the organism reaches a state of "equilibriation",[7] when the performance output needs to be maintained at a reduced functional level due to a reduced frequency of dis-

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[9] Sherrington (1906) p. 105, Kuffler (1955) p. 178, Hemingway (1953) p. 70, Brown (1949) p. 193 f.

[1] Purpura p. 435.

[2] Burns p. 182 f., cf. Brink (1951) p. 59 ff. Gualtierotti demonstrated that "the inhibition lasts for several minutes after the end of the stimulation" of the brain centres (p. 414).

[3] Forbes (1929) p. 144.

[4] Bills (1931) p. 230.

[5] Brazier (1953) p. 33.

[6] Adrian (1932) p. 23.

[7] Gerard (1927 b) p. 497. The author proposed the term to signify the difference between this condition and real "fatigue" that leads to exhaustion (ibid. cf. (1927) p. 401 f.).

charging impulses.[8] In other words, during the period of repeated task performance, the organism exhibits a state of 'adaptation',[9] which is a characteristic feature of the synapses[1] involved in the conduction and transmission of impulses.

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[8] Gray (1959) p. 124.

[9] Nafe p. 199. Adaptation is regarded an an "example of ... a disturbance of the surface charge which prevents the building up of impulse discharges at the maximal rate" (Brazier (1953) p. 116, Adrian (1932) p. 24 f.).

If a repeated stimulus continually stimulated various receptors to fire, "the brain would be barraged with so many impulses that it could not sort them out for interpretation" (Guyton p. 533). Adaptation therefore, helps "the sensory receptors to perceive the rate of change of sensory intensities as well as to perceive the absolute sensation itself" (ibid. p. 534, cf. Brazier (1953) p. 116).

Lorente de' No (1948) suggested an alternative theory of adaptation or "accomodation of nerve" according to which a constantly applied stimulus sets up an opposing reaction that tends to stabilize the nerve fibre (p. 90 f., cf. Granit (1955) p. 26). From this point of view "accomodation is the result of an active process" (Lorente de' No (1948) p. 92).

Brazier (1953) makes a distinction between adaptation and "fatigue". 1. In reference to time relation "adaptation not only sets in more quickly but recovery from it is almost instantaneous upon the removal of stimulation". 2. Adaptation is independent of "oxidative processes" while fatigue may be "induced quickly by oxygen deprivation". 3. The adapted nerve showing characteristics of absolute unresponsiveness to a repeated stimulus may be made "to respond instantly to an increase in intensity of stimulus ... thus demonstrating that its excitability is preserved" while a fatigued nerve exhibiting unresponsiveness "cannot be excited by any change in intensity of stimulation" (p. 116, see also Sharpless p. 655, Nafe p. 208).

[1] Granit (1955) p. 24. Adrian (1940) demonstrated that the end-organs of pressure receptors in a cat's-toe show a slow rate of recovery and longer refractoriness during repeated stimulation (p. 17 f.) Adrian (1930) has also shown that the maximum rate of frequency of discharge in sensory nerves is far in excess of that in any end organ of skin or muscle (p. 343 f., (1926 a) p. 47 ff., (1926) p. 57 ff.).

According to Sharpless organisms having synaptic nervous systems provide samples of several forms of response decrement, viz. "sensory adaptation, nerve accomodation, effector fatigue ... association fatigue, internal inhibition ... negative adaptation" (p. 655). He uses, however, a comparatively neutral term "habituation" for such response decrements. But Thorpe considered habituation as different from fatigue and sensory adaptation, and defined habituation "as the relatively permanent waning of a response as a result of repeated stimulation which is not followed by any kind of reinforcement. It is specific to the stimulus and relatively enduring" (pp. 54–55).

Conclusion

The above mentioned physiological considerations indicate that the junctional mechanisms concerned during the period of continued task performance, while they may sometimes modify the output to some extent because of delay or reduced intensity of the response during repetitive stimulation, do not during a moderate task appear to be directly involved as the causal agencies in bringing about appreciable changes in output. In view of this we may now turn to investigate the psychological factors which lie behind the output changes and which may throw more light on the problem.

CHAPTER V

THE PSYCHOLOGICAL BACKGROUND MOTIVATIONAL PROCESSES

Changes of output are of course closely related to motivation and its intensity. But we must also consider the question of inhibition, and inhibitory factors are in their turn dealt with in relation to motivation. Therefore we first have to discuss inhibition and motivation as influencing forces during the period of continuous work.

Inhibition and motivation

Some considerations indicate that during a period of continued performance repetition of task processes delays or reduces the intensity of response.[1] The temporary delay or the causal breakdown in the chain of responses can be due to the deterioration "in the phase sequence instead of the assemblies that compose it: that is, in the relation between constituent parts, not in the parts themselves".[2] Performance of homogeneous and continuous learning tasks prolong the phase sequence which tends to create a deliberate weakening in the bond of the assembly resulting in gradual deterioration of response. There are several other sources[3] according to which conditions of massed reinforce-

[1] Miller (1946) states that "mere repetition does not strengthen a habit. Instead, non-rewarded repetitions progressively weaken the strength of the tendency to perform a habit" p. 42.

Dunlop (1928) p. 360 f., Thorndike (1931) p. 162 ff., and Köhler (1947 a) p. 257 ff. have shown that greater frequency does not always strengthen an associative connection and even the reverse may be true.

[2] Hebb (1949) p. 226.

[3] Bugelski p. 287, 349 f., Hovland (1950) p. 616, Hull (1943) p. 289 f., Hilgard (1940) p. 146.

ments or a sufficient number of trials eventually lead to a decrement in the strength of conditioned response. Deese[4] states: "If during conditioning, trials are massed very close together, the animals may slow their rates of responding and even stop altogether, even though the reinforcement is still present . . ." The genesis of this decreased response phenomenon is termed "inhibition of reinforcement" in accordance with the work of Hovland.[5] Hull treated the phenomenon of "inhibition of reinforcement" in a more formal manner. His 13th corollory is that "in the case of closely massed reinforcements the curve of acquisition of effective excitatory potential ${}_{s}E_{r}$ particularly in its later stages, will be distorted by 'inhibition of reinforcement' . . . in extreme cases showing an actual fall with continued practice".[6] This means that continued reinforcements would produce inhibition which in the end would offset the effects of reinforcement, resulting in diminished performance output although the reinforcement is not withdrawn.

But Hull[7] in his final work did not mention "inhibition of reinforcement". The phenomenon of decreased output in connection with massed practice is well known.[8] Deese[9] talks about it as "a matter of experimental fact". But new explanations have been attempted. Output decrement consequent upon response repetition may as mentioned be a function of diminished intensity of motivation.[1] But this can also be a sort of "negative motiva-

[4] Deese (1958) p. 53.

[5] Hovland (1936) p. 430. In his later work Hovland (1950) himself discusses performance decrement without using the label 'inhibition of reinforcement', Unlike Deese (1952) p. 56. Bugelski p. 287, Razran p. 412 f., and Solomon (1948) p. 1 ff.

[6] Hull (1943) pp. 290–1.

[7] Hull (1952) p. 1 ff.

[8] Deese (1958) p. 53 f., (1952) p. 56 f., Rock (1957) p. 193, (1958) p. 68 ff., Bugelski p. 287 f., Hovland (1950) p. 616 f., Hilgard (1940) p. 146 f., Prokasy p. 238 ff.

[9] Deese (1958) p. 53.

[1] Hemphill observed that "it is a common place that the normal individual who complains of real fatigue, mental and physical, when performing an uninteresting task, presents exactly the opposite picture, objectively and subjectively, when doing something agreeable immediately afterwards" (p. 433). Hebb (1949) stated that "loss of interest" contributes to fatigue (p. 208).

Weiskotten worked out extensive tests in pure motor learning, sensory

tion" or a "fatigue drive".[2] Thus Hull, in his later inhibitory postulate, states that "whenever any reaction is evoked in an organism there is left a condition or state which acts as a primary negative motivation in that it has an innate capacity to produce a cessation of the activity which produced that state".[3] The so called reactive inhibition that is associated with continuous performance brings about a certain reaction decrement which Hull believes to be closely related to "fatigue" as being "akin to tissue injury or pain".[4] He also refers to another form of inhibition where "stimuli closely associated with the acquisition and accumulation of inhibitory potential (I_r) become conditioned to it in such a way that when such stimuli later precede or occur simultaneously with stimulus situations otherwise evoking positive reactions, these latter excitatory tendencies will be weakened".[5] This class of inhibition is referred to as "conditioned inhibitory potential".[6] Simple reactive inhibition (I_r) is transitory, dissipating after a time, and summates with conditioned inhibiton ($_sI_r$) to give the total inhibitory potential ($\dot{I}_r$)[7] operating at any time during the period of continued task performance.

Hull's[8] discussion of the various properties of the intervening inhibitory variable associated with fatigue of output decrement arises from his theoretical assumptions and logical constructs

motor learning and abstract learning. He concluded that "fatigue itself does not lessen ability but serves to affect those factors of motivation, interest, initiative, attention and concentration, which are necessary to the learning processes" (p. 266).

Mcworth's (1950) extensive research in continued vigilant task performance p. 7 ff.), and the work of Kefauver p. 30, Whiting (1925) p. 49, and Manzer p. 49, further demonstrate the same fact.

[2] Osgood (1953) pp. 340–1, cf. Davis (1953) p. 179.

[3] Hull (1943) p. 278.

[4] Hull (1943) p. 281.

[5] Ibid. p. 282.

[6] Ibid. Hull (1951) attempted to demonstrate the interrelationship of the two inhibitory components, the drive and the habit strength, as well as the nature of I_r and $_sI_r$ (p. 75), on the basis of Kimble's (1949) experimental findings which unfortunately have procedural errors (p. 20 ff., cf. Schucker p. 101 f.). However, the later experiments of Kimble (1952) p. 355 ff. and Eysenck (1956 a) p. 350 ff. have established the case for $_sI_r$ with a different experimental task overcoming Kimble's (1949) procedural errors.

[7] Hull (1943) p. 283.

[8] Ibid. p. 281 f.

which are not always subject to direct observation. There are considerable difficulties in subjecting the inhibitory postulates to a satisfactory experimental verification. As a result they have been subjected to considerable criticism.[9] As regards performance output decrement Hull[1] attempted to relate the development of inhibition to a given amount of work done on the lines of an earlier study of extinction of response during effortfulness of task performance.[2] He says "the net amount of functioning inhibitory potential resulting from a sequence of reaction evocations is a positively accelerated function of the amount of work (W) involved in the performance of the responses in question".[3] But several experimental findings report that it is independent of effort.[4] It is true that Patel[5] established "that the greater degrees of effort during practice were accompanied by greater accumulation of inhibitory decrements". But he was able to control the psycho-motor learning task of his subject during performance. Only under special conditions when the manipulations of effort are under control,[6] thus avoiding the depression of responses, and when at the same time the experimental subject at different effort levels works for the same length of time, may the proportionality between effort and I_r hold good.[7] Under these circumstances it is difficult to defend the generality of work hypothesis of inhibition and Eysenck[8] "suggests that this part of the inhibition theory should be dropped". But with this exception Hull's theory of reactive inhibition as a negative drive, resulting also in a conditioned inhibition, seems to have been widely accepted.

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[9] Eysenck (1957) p. 53 ff. Koch in a detailed critical study shows the inherent contradictions in Hull's theory and the failure of experimental studies to agree with parts of his hypothetical constructs (p. 1–169).

[1] Hull ibid. p. 279.

[2] Mowrer (1943) p. 384 f.

[3] Hull ibid.

[4] Bilodeau (1952) p. 389, cf. (1952 a) p. 100, Helmic p. 137.

[5] Patel p. 1395.

[6] Payne (1957) under constant conditions of task performance showed that "the residual inhibition at the conclusion of the reaction sequence was a negative growth function of the length of the intertrial interval" (p. 5).

[7] Ellis (1952) p. 425 f.

[8] Eysenck (1957) p. 55.

Output decrement associated with "negative motivational state" is a special case relating to the drives and motives of the individual, which in their turn are connected with the native capacities and mechanisms that come into play during task performance. Forty years ago instincts were considered to be the main basic motives, implying activity "driven from within".[9] Early physiologists and psychologists "were thinking of instinct as primarily some sort of innate urge for activity directed towards ends (and) considered 'instinct' to be the same as motivation".[1] In one of his works Mcdougall[2] asserts that "instinctive impulses determine the ends of all activities and supply the driving power by which all mental activities are sustained (and in their absence) the organism would become incapable of activity of any kind: it would lie inert and motionless like a wonderful clock work whose main spring had been removed or a steam-engine whose fires had been drawn". The role of many instincts as factors in motivation, as suggested by James[3] and Mcdougall,[4] is disputed; according to Watson[5] "the whole concept of instinct is ... academic and meaningless", and Kuo[6] suggested that the concept of instinct be entirely done away with in discussions of behaviour. Current discussions on motivation do not appear to emphasize the importance of instinct.[7] For instance Benedict's[8] anthropo-

[9] Thorpe p. 14.

[1] Thorpe p. 14. Parker in emphasizing the role of instinct says "all human activity ... is untiringly actuated by the demand for realization of the instinct wants" that direct and canalize our conduct (p. 137, cf. Dickinson p. 95 ff.).

[2] Mcdougall (1950) p. 38.

[3] James (1910) p. 403 ff.

[4] Ibid. p. 39 ff. Sargent states that "the sociologist Bernard reported a survey of some 400 instincts theories and found that, among them, almost 6000 human urges or activities had been called 'instincts' or 'instinctive'" (p. 161).

[5] Watson (1925) p. 104, (1928) p. 22 ff., (1958) p. 93 ff.

[6] Kuo p. 428.

[7] Hayes (1950) for example does not defend the instinct hypothesis where social behaviour has some relevance to social situation (p. 299 f.). The author has given an excellent review of the economics of behaviour (p. 290 ff.).

[8] Benedict (1934) p. 21 ff.

logical studies, which indicated variation of human behaviour under different cultural patterns, have lead to an attempt to explain the varied activity in terms of a broader and more systematic approach to motivation. Such an approach resulted in the work of Cannon[9] and Richter[1] etc., who attempted a more penetrating analysis of the biological mechanisms involved in the psychology of motivation. Although these attempts did not result in absolute abandonment of the instinct hypothesis,[2] the "bio-chemical core"[3] involved in the organism's behaviour in response to "appeted stimulus"[4] is more concerned with the "translation of bodily needs into behaviour".[5] Some psychologists are inclined to the view that the instinct concept belongs to a wider class of behaviour related to the mechanisms usually referred to as needs, drives and motives.[6]

Now motive is considered to be "a generic term to cover all the different cases and kinds of goal directed behaviour".[7] Muenzinger's[8] definition of motive refers to the direction and strength of psychological movement. It is pointed out that while the direction of motive remains constant within limits its strength or tension may vary. Within this framework a motive may be defined as an internal process that determines the direction of movement in a behaviour unit. The definition also implies the persistence of this process throughout the unit. Peak[9] also considers motivation as a process having an energy aspect and a directional aspect. Motive according to Shaffer too appears to be a complex structure made up at once of a set of factors such as

[9] Cannon (1939) p. 268 ff., (1932) p. 61 ff.

[1] Richter (1941) p. 193 ff.

[2] Fletcher (1957) in his recent work on the theory of instincts concludes "that the major ends of human activity are rooted in the instincts, and that instinctual experience ... (exerts) a far reaching influence upon conscious and rational activity in both individual and social life" (p. 303).

Thorpe states that "only instinct has an internal drive or motivation in sense" (p. 14, Sargent p. 162, Tolman (1958) p. 22, Kubie p. 29).

[3] Kubie p. 16.

[4] Dell (1958) p. 188.

[5] Kubie p. 17.

[6] See for instance Woodworth (1918) pp. 74–75.

[7] Sherif (1948) p. 11.

[8] Muenzinger p. 35.

[9] Peak p. 159 ff.

"situation (need), drive, mechanism, and end-result".[1] In order to identify motive involved in the behavioural processes it may therefore be necessary to "specify the need or situation that gives rise to it, the drive or tension that operates, the behaviour or mechanisms that result, and the adjustment that will bring the sequence to a close".[2]

At the bottom of this concept of motives we have Cannon's principle of disturbed homeo-stasis.[3] Need and drive are of course interrelated, but need is generally referred to as "a condition in which the animal is impelled to persistent activity until equilibrium is restored" or as "the physiological state of deprivation".[4] Drive is theoretically conceived as something which results in activity "when a need exists"[5] or as "the psychological consequence" of a need state.[6] The need-drive-component pushes the organism to activity, until the organism has hit upon those actions which remove the drive stimuli.[7] These actions are then learned, and we get a mechanism, "a response or a sequence of behaviour that tends to reduce a drive".[8] This is the same as saying that "we learn to recognize many of our goals".[9] In this way the urge to activity in the concept of instinct is replaced by needs and drives, and the native goal-seeking of the organism is changed to a learning-process with incentives as a result of activity instead of being an original guide to it.

Motivational processes thus based on disequilibrium and described either in physiological or psychological terms include specific chemical reactions of blood and tissue, organic deficit and pressure, muscular sets, states of disequilibrium in the nervous system as well as verbalized behaviour of purpose, thought, images, differentiation, integration and condition processes. Dis-

[1] Shaffer (1956) p. 85.

[2] Ibid. cf. Boring p. 126.

[3] Cannon (1932) p. 77 ff.

[4] Hilgard (1956) p. 423.

[5] Hebb (1958) p. 155. The experiments on psychic satiation where the organism attains a state of equilibrium when its psychological needs are met to its satisfaction are also relevant (Seashore (1942) p. 283, Berman (1939) p. 472, (1939 a) p. 298 f.).

[6] Hilgard ibid.

[7] Shaffer (1956) p. 23 ff.

[8] Ibid. p. 29.

[9] Ibid. p. 95.

cussion of the variety of motives[1] has resulted in their classification with the aid of such terms as needs and drives but also with concepts like wants, wishes and desires.[2] The large variety of motives which are rooted in the main springs of human behaviour, and related to the operation of biological mechanisms, are commonly referred to as primary motives. The other class of motives, multiple in character, resulting from interaction of the organism and its environment through various processes of integration, differentiation and conditioning etc., are generally classified as secondary motives.[3]

[1] Cantril p. 33 f. Experimental verifications are not unanimous in identifying the variety of motives (Freeman (1938) p. 282, (1930) p. 309 ff.).

[2] The terms are frequently interchanged in discussions on motivation. Lindsley (1957) states that "some do not distinguish between drives, needs, motivation and incentives or if they do, inevitably talk most about one or another, rather than all, after the introductory formalities are over" (p. 45). However, in regard to biological mechanisms attempts are made at clear distinction (Wenger p. 315 ff.).

[3] Mowrer (1945) p. 79. Other similar classifications are biogenic and psychogenic (Morgon (1943) p. 437); true needs and quasi needs (Lewin (1954) p. 946 f., 955); phäno-motives and geno-motives (Stern p. 569).

There are many detailed variations in classifications of motives within these two major divisions. However, considerable difficulty is involved in precisely identifying a particular need with a motive either secondary or derived due to the richness and complexity of human motives. The result is a confusion in concept through loose usage which generally reflects the personal preferences of various writers. Thus in discussions of complex motivated behaviour one writer speaks of need for recognition (Murray (1938) p. 145), another of striving for status (Harsh p. 168), and Granich's list of terms and definition of motives give an interesting picture of looseness (p. 240 ff.). Newcomb subdivides secondary motive to produce a third class of personal motive which is peculiar or 'private' to the individual and not shared by most members of the group (p. 459 f.). Maslow (1954) summarized 13 main propositions of human motives. But his classification is coloured by emphasis on secondary motives. He proposed a synthesis of all the postulates in a new concept of "holistic-dynamic theory" (p. 80, ibid. (1943) p. 370 f., Sappenfield p. 34 ff.).

According to Murray (1958) "we should include mental needs, as well as somatic, material, and social needs in our inventory of human motivation" (p. 184).

Thorpe states that "to classify innate drives into such mixed categories as homeostatic, physiological, mating, maternal, etc., ... is a confusion of ideas and is apt to be misleading" (p. 15). Hebb (1958) stated that it is quite unnecessary "to assume the existence of a special drive for each different form of behaviour" (p. 160) cf. (White p. 328 f.).

Of course there are also difficulties with this concept of motives. Tsang[4] has shown that hunger drive is present when there is lack of stomach contraction and hungry rats were as well motivated as normals. Montgomery's[5] experiments on the extirpation of salivary glands in dogs did not increase the average intake of water and he concluded that "it appears improbable that the salivary glands play a major role in the thirst mechanism".[6] Davis[7] stated that "homeostasis would not serve as a good allround model for behaviour". In fully accomplished and optimal motivational behaviour involved in primary need deprivation, the reinforcement value of the reactive stimulus can only be understood after the animal has had ample opportunity to learn a given response. In such a situation "variety seems to act very well as a reinforcer ... and the animals seem to be able to react to a 'promise of novelty' at a spatial and temporal distance".[8] Thus Jencks contends that "primary reinforcement should be so defined as to include novelty".[9] Experimental evidence seems in this way to restrict the scope of the theory of organic needs. There are also difficulties in identifying a particular need that would correspond to a particular motive.[1] Similarly, specification and definition of acquired needs and drives are difficult as they are changeable and subject to interrelationships among them-

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[4] Tsang p. 15 f., Bash (1939) p. 131 f., (1939 a) p. 158.

Experimenting on food deprivation Campbell (1953) stated that "hunger drive seems to involve lower thresholds of response rather than internal stimulation to activity. The slight rise in general activity as the animals are starved over a three day period is interpreted as due to their greater sensitivity to minimal stimulus changes in the environment provided. This rise was small relative to the rise in the effects of a large environmental change during the same starvation period. Starvation does not instigate activity" (p. 321, Campbell (1960) p. 241, Teghtsoonian p. 243). Similarly Devito has shown that "the activity of the monkeys did not change when they were deprived of food for periods as long as 54 hours" (p. 31).

[5] Montgomery (1931) p. 225 f.

[6] Ibid. p. 227.

[7] Davis (1958) p. 13.

[8] Jencks p. 142.

[9] Ibid.

[1] Bird's experimental enquiries reveal a close involvement of glandular mechanisms, hormones and tissues in motivational states (p. 36 f.).

selves.[2] In view of these complexities Ryan[3] "urged a re-examination of ... purposes and ... ways of thinking about problems of motivation". Therefore a reorientation in different directions may be recognized. Hebb for instance has identified drive with arousal or activation[4] and some psychologists have also laid more stress on "the positive role of incentives".[5] But none the less the former points of view may still be said to be the most common.[6]

We may now attempt to understand the role of the motivational processes in performance output variations. It was observed that during task performance the organism spends energy, and for its survival energy-holding material is needed. The chemical characteristics of tissue maintenance, acidity, water content of the blood, oxygen supply etc.[7] vary "with the intensity of the need".[8] When such vital necessities are wanting during task performance the organism remains in a state of need.[9] In addition

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[2] Miller (1946) p. 65 ff. Hebb (1958) states that it is difficult to explain "the motivation to explore and to manipulate the environment, or to escape from conditions of monotony, ... on the basis of escaping from pain or conditions associated with pain (alone) ... there are aspects of motivation that cannot be reduced to ... one drive" (pp. 158–159).

[3] Ryan (1958) p. 92.

[4] Hebb (1958) p. 159. For a detailed interpretation of the arousal system with the drive state see Bindra (1959 a) p. 210 ff.

In a recent review Cofer states that "motivation as a distinctive concept, coordinate to other psychological concepts may well disappear" (p. 194). With the increasing progress of neurophysiological investigations more especially of a closer understanding "of the reticular formation functions, hypothalamic centres and stimulation of the limbic system ... perhaps a new model of motivational phenomena will emerge" (ibid.).

The intimate relationship of these central nervous functions more especially of the ascending reticular activating system to the psychology of motivation understood as directedness and persistence of behaviour is well explained by Lindsley (1957) p. 94 ff. Lansing demonstrated that the "behavioral alerting or attentiveness (could) be identified with an alerted or attentive state produced through action of the (ARAS) resulting from sensory stimulation and instrumental set" (p. 6, cf. Miller (1957) p. 1276 f.).

[5] Hilgard (1956) p. 427 ff.

[6] Kornhauser p. 65, Sjöstrand (1958) p. 238.

[7] Bindra (1959 a) p. 258 ff.

[8] Osgood (1953) p. 340, Guthrie (1950) p. 8 f., Cannon (1932) p. 24 f.

[9] Richter (1947) demonstrated the concrete biological urges of mammals for water balance, body temperature, sodium and calcium balance, fat and protein balance to maintain a constant internal state as the basis for under-

deprivations of a psychological nature may be conceived where organic needs may not play a predominant role. For example there may arise a need to "achieve a satisfactory standard of work or gain a satisfactory degree of control over ... environment"[1] involving different sensory and muscle coordination, manipulation and sensory discrimination. In problem situations that "arise from the anticipation of psychological dangers"[2] one may attempt to overcome them by gaining mastery over the task and the environment. Such states of the organism may also be termed needs, although generally considered as a secondary type.[3] Thus performance output changes are associated with the primary as well as the secondary motives for the organism during its task performance.

An important aspect of the state of the organism under motivated conditions of task performance as observed by Guthrie[4]

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standing motive forces or drives (p. 130 ff.). Further such instances of maintenance of constant internal environment by selfregulating activities have been observed in farmers, cattle, pigs, chicken, patients, children, hunters and naturalists etc. (ibid. p. 133, cf. Bare p. 250).

Dell (1958) showed "that variations of some of the main metabolites and hormones of the 'milieu intérieur' produce reticular activation and consequently arousal effects, enhanced alertness and motor facilitation, (and these) consequences of change in the internal environment, can even be more graduated, more powerful and more long-lasting than those introduced by change in the external environment" (p. 187, (1958 a) p. 365 ff., Hebb (1958) p. 64, 165).

[1] Davis (1953) p. 181.

[2] Ibid. p. 180.

[3] Miller (1951) p. 436 f., (1948) p. 97 ff., (1946) p. 57, Murphy p. 161 f., Hull (1951) p. 21 ff.).

Wolfe's experiment with chimpanzees involving valuation of poker chips where means become ends may be considered as an example of secondary drives (p. 70 f.).

Saltzman found that "secondary reward may be as effective as the primary reward of food in influencing the choice made in a maze" (p. 173).

Bare has shown that the primary urge for salt in animals may acquire "secondary reinforcing properties as a result of the previous experience of the animal" (p. 251).

[4] Guthrie (1950) p. 93 ff. Dell (1958) states that the animal exhibits an external "state of agitation ... at first a vague unrest, undirected random locomotion, then more and more pronounced restlessness" due to absense of 'appeted stimulus' "concerned with changes in the internal environment e. g. disturbances in the homeostasis of metabolites and hormones" (p. 188).

is the increase and vigour of movements which at the beginning are random and undirected. The undirected movements involved in task performance may be orientated towards the achievement of some purpose by appropriating the activity in a directed and persistent fashion.[5] In other words the released energy derived from task performance may be canalized into a chain of phase sequences that could culminate in a purposeful end. Muenzinger[6] pointed out that an organism moves from a disturbing situation to a relatively quiescent phase, or what he calls "the start-to-end-phase cycle of behaviour". Between the two poles of the 'start' and 'end' phase of a motivated unit of activity there is a state of tension, necessary for initiation, maintenance and direction of effort.[7] Changes in effort are then reflected in the output.

Motivation and "warming-up"

In discussions of curves of work a period of "warming-up" at the beginning distinguished by a slowly increased output is generally mentioned. Thorndike[8] considered that the importance of this increment "has commonly been exaggerated".[9] He regards the data bearing on the subject of output increment as "warming-up" to be almost impossible to separate from "the more permanent improvement that comes from exercise of the function in general",[1] which would generally be called practice effect. But Crawley[2] found increased output resulting from motivation of the subject due to knowledge of results, though like Thorndike he partly attributed the increased output to practice effects. Payne[3] reported increased output as well as increased task profi

[5] Hebb (1955) points out that the brain is always active, but the activity may not be always of the transmitted kind that is conducive to behaviour (p. 246).

[6] Muenzinger p. 35.

[7] Shaffer (1936) p. 89, cf. Symonds p. 24 f., Wenger p. 313.

[8] Thorndike (1926) p. 66 f.

[9] Ibid. p. 67.

[1] Ibid.

[2] Crawley p. 49 f.

[3] Payne (1955) p. 351, Mcpherson (1949) p. 173 f., (1948) p. 78. Payne, however, reported that the increased performance output and proficiency "was not maintained ... under analeptic and depressant conditions" (ibid.).

In a study of a number of industries Schwellenbach reported that "with

ciency and such "increment was a positive function of the specificity of the information supplied and it remained essentially constant for the duration of the task". Heron[4] established statistically that warming-up is present during the learning of a list of nonsense syllables apart from "transfer of specific habit-units (and) practice effects". The fact of "warming-up" seems in other words to be well evidenced, and the explanation is often what Thorndike has already given as "the diminishing annoyance of a process due to the progressive inattention to competing desires, interest in achievement, and the like".[5]

The increased output involved in the warming-up period has, as mentioned by Thorndike himself, been closely associated with practice and is so related to his conception of "success".[6] What he calls rewards strengthens the connections between a given stimulus and the response which leads to the success. But it has consequences also in relation to set and attitude. Thorndike has of course not forgotten that the set and attitude of the subject play an important role in learning behaviour. They are rooted in the needs of the organism, and they determine what a man "will be satisfied or annoyed by".[7] This complex of orientation responses and readiness is, however, influenced in its turn by successful action. Therefore the practice effect of "warming-up" cannot be merely explained by "the mechanical influence of the result of the connections in the nervous system".[8] The successful accomplishment of the task involved in the response repetitions to the items presented during the experiments "puts the subject into a state of persisting 'task tension' in regard to each item of the series".[9] It would follow that reinforced connections during task repetitions are not the only results of the successful reaction of the subject, as appears to be implied in Thorndike's[1] statement

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the introduction of an incentive system (performance) resulted in an increase in efficiency of 24 percent and in output 10 percent above the levels which prevailed at the longer hours" (pp. 50–51).

[4] Heron (1928) p. 227.

[5] Thorndike (1926) p. 76.

[6] Ibid. (1930) p. 4.

[7] Ibid. p. 13 f., 24 f., 65 f.

[8] Nuttin p. 49.

[9] Nuttin p. 50.

[1] Thorndike (1930) p. 2 f.

of the 'Law of effect', but there is also a real "warming-up" in the form of an increasing task-tension that results in better performance output. We get in other words at the beginning of a working period a sort of feed-back mechanism. The original motivational state determines the set and attitude, but success will refresh them and make them more powerful, which then results in greater success and so on. There is a successive accumulating, a "warming-up" with its slowly increased output.

Output decrement and conflicting motives

Output decrement may be a function of inhibitory tendencies of rivalry and competition between responses claiming priority against one another during continued task performance.[2] That is, an activity is inhibited when some other behaviour system takes its place.[3] Dodge's study of reflex eye movements also leads him to interpret the process as one in which two response systems are in rivalry and competition, and he puts the competition in relation to diminished original motivation, resulting in the weakening up of other motives and their activity tendencies. Dodge talks here about a law of "relative fatigue".[4] Wendt[5] repeated the experiment on condition reflexes and "assuming that behaviour is organized into response systems his experiments present ... evidence for the point of view that the inhibition of complex behaviour is one aspect of the process of competition between reaction systems. That is to say, an activity is inhibited, when some other reaction takes its place". He thus at least confirms Dodge's experimental findings. The reactions in gaining control over competing responses are evident in Dockery's[6] experiments on distractions and are more common in motor and mental ac-

[2] Sherrington (1906) p. 223, Osgood (1953) p. 339. Norris showed that the periodic inactivity of excitable motor units during prolonged performance is "probably due to conflict of excitatory and inhibitory influences at some undetermined level of the neuraxis" (p. 124).

[3] The work of Creed shows that all inhibitions of the spinal cord are reciprocal inhibitions (p. 87 f., Sherrington (1906) p. 140 f., Ash p. 56 ff.).

Mcdougall (1929) systematically develops the competition of behaviour in support of his drainage theory of inhibition (p. 238 ff.).

[4] Dodge (1923) p. 169 ff., (1926) p. 9 f. and (1917) p. 105 f.

[5] Wendt p. 280.

[6] Dockery p. 340 f., cf. Fernberger p. 149 f.

tivities. The state of affairs associated with competing and rival tendencies during response effort causes drift in attention[7] and decline in the smooth performance of task processes. The disturbance in "attention coordination"[8] due to the presence of inter-competing tendencies is associated with "the occurrence of blocks (and) this is supported by the association of errors with blocks, particularly when blocks follow the errors".[9] That the occurrence of errors consequent upon inter-competing tendencies cause diminished performance output is well reinforced by experimental findings. Geildreich[1] showed that the "block is ... a function of response competition ... and is forced by the task pressure to reorient attention, (hence) alertness diminishes (and) loss of control is evidenced by the increasing frequency of ... blocks".

Robinson has also referred these consequences of inhibition as competition to Dodge's above-mentioned law of "relative fatigue".[2] This point of view is the more interesting in that we have to consider it in relation to the state of boredom, growing during continuous work.

Boredom and performance

Thorndike's[3] extensive investigations in continuous performance showed that the task processes were characterized by "slowness of association, lack of inhibition of irrelevant ideas, interference with purposive trains of thought by feelings of ennui, of

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[7] Warren (1937) p. 104, Dockery p. 369.

Huxtable, repeating Arai's experiments in continuous arithmetical work in a four day fatigue series, observed that "each (subject) held on to some escape mechanism ... attention may be called to the interesting fact that every subject, including Arai, by way of protecting herself from the exacting concentration of task, at the time, prepared for herself an ever so subtle means of partial escape" (p. 21).

[8] Dockery p. 369, cf. Bills (1931) p. 244, Freeman (1935) p. 151.

[9] Warren (1937) p. 104. Siddal's experiments on continuous tracking report that when "the task demanded continuous attention ... mental blocks or gaps in the perceptual response would occur causing tracking to become momentarily uncontrolled (and) the increasing evidence of errors with time, may be taken as supporting evidence" (pp. 164–165). Vince (1949) further confirms this by his experimental findings (p. 38 f.).

[1] Geildreich p. 27.

[2] Robinson (1926) p. 129 ff., and (1934) p. 614 ff.

[3] Thorndike (1900) p. 480.

bodily pain and strain, thoughts of pleasant activities, impulses to stop work, mental confusion, sleepiness, physical fatigue of the eyes, and perhaps a number of other things". In this state of affairs continuation of task processes causes "the pupils (to be) bored by the triviality and repetitiousness of the instruction".[4] According to Thorndike, we are bored when the work loses its novelty (we become "tired of" the work), when it produces "ennui" or "an intellectual nausea", and prevents us from doing other interesting things. Therefore "fatigue" can be abolished "by washing out ennui and repugnance by inattention of counteracting them by interest and motive" and not by resting but by "indulging wants which mental work proscribes".[5]

Discussion has followed this line of thought. Barmack[6] defined boredom "as a state of conflict between the tendency to continue and the tendency to get away from a situation which has become unpleasant, principally because of inadequate motivation ... during the operation of a task set". The state of boredom is specifically referred to the inclination of the subject rather than to the effectiveness or capacity of task performance. Administering 10 mg. of benzendrine sulphate Barmack attempted to determine the rate and accuracy of the continuous two hour addition of six figure numbers involving a state of boredom. He found that the drug retarded the rate of addition by a certain drop and also the development of boredom, sleepiness and fatigue. But the accuracy of task performance remained more or less unaffected while there were variations in the rate of work with an increasing work period. Thus he concluded that "the effect of benzendrine ... is not particularly on the ability but on the inclination to do continuous, repetitive work".[7] In an attempt to understand the nature of output variation during continuous performance in industry Wyatt[8] found that "the rate of working cannot be maintained at a constantly high level during an unbroken spell of four or five hours, but is retarded and increases

[4] Ibid. p. 569.

[5] Thorndike (1926) p. 122 ff.

[6] Barmack (1938) p. 125, (1937) p. 68.

[7] Barmack (1938) p. 132.

[8] Wyatt (1928) p. 2, cf. Viteles p. 522 ff. See also other papers published by Wyatt under Industrial Fatigue Research Board, London.

in variability, ... whilst at the same time voluntary stoppages tend to become more numerous, (a tendency which is) attributed ... to the inhibiting effects of boredom and fatigue". By introducing suitable rest pauses as "changes in the form of activity at suitable times within the spell of work (they obtained) increased output and personal satisfaction"[9] among the workers, thus supporting Barmack's conclusions. As far as the effects of boredom are concerned, Hollingworth's[1] results obtained with thoroughly practised subjects showed that the variations in the efficiency of "work mechanism (are) not due to organic rythms or diurnal factors" but to work. Super's[2] findings that "lack of similarity of job requirements to individual abilities and interests" and that "the nature of the work itself appeared as the most frequent reason in the minds of the men themselves, for disliking a job"[3] are much on the same lines.

The state of boredom evidently begins to express itself in the absence of psychological wants in the nature of the task, which influences the inclination of the individual's motivational state. Under these circumstances the organism tends towards a new state of drive, because a "reduced level of motivation (develops) ... involving a distaste for the work, a desire to cease work".[4] But Berman,[5] it is true, considered Barmack's[6] explanation of boredom as reduced motivational state to be not wide enough in treatment. He appears to identify boredom with satiation by extending the

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[9] Ibid. In the classic experiment of 12 hours continuous mental work in a four day fatigue series with previously well practised subjects, Huxtable found that the subject 'Z' "settled down to the performance of (some other) kind of work which could satisfy her. As a consequence, and quite unwittingly, she performed more efficient work during the final two hours of the fourth day than during the first two hours of that day" (p. 21).

[1] Hollingworth pp. 490–491.

[2] Super p. 555.

[3] Ibid. p. 562. Huxtable, extensively repeating Arai's classic continuous and strenuous mental work, showed that the consequences of "fatigue" evidenced in various forms was definitely in relation to the nature of the task and not to the ability of performance which further confirms the previous findings (p. 20 ff.).

[4] Ryan (1947) p. 197, Hull (1943) p. 278.

[5] Berman (1939) p. 471 f.

[6] Barmack (1938) p. 128 f.

term originally used by Lewin[7] for psychological activities to all activities. He states "satiation involves more than a reduction of motivation during the task".[8] But there are some differences in the experimental tasks and procedures of the two authors. Berman's[9] experimental tasks involving maze activity, drawing faces etc., were comparatively more heterogeneous in character and the subject was "free to stop ... as soon as he (had had) enough of it".[1] Barmack's[2] experiments on the other hand involved homogeneous addition of a two hour duration and "the subject (was) acting under the constraint of the experimenter's instructions to complete a specified period of activity".[3] This meant that the experimental subjects, in conforming to the instructions were less free to stop the work at their will. While homogeneous and continuous task performance does lead to satiation and boredom, Barmack however, in his reply to Berman, failed to take into account the fact that heterogeneous tasks "despite the profession of sustained interest in the task"[4] may also be subject to satiation, as indicated for instance by Seashore's[5] experimental findings. Thus the author unfortunately missed the role of "the limited variation in sensory output"[6] and the related consequences in the wider problems of diminished motivational processes in the state of boredom.

Involved in the bored state there is however not only the growing disinclination for task. There is also a state of "conflicts ... in the cause of discomfort and fatigue".[7] The competing reactions in this case are between "what one wants to attend to

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[7] Lewin (1928) p. 153 ff.

[8] Berman (1939 a) p. 298.

[9] Ibid. (1939) p. 472.

[1] Lewin (1935) p. 254.

[2] Barmack (1938) p. 128.

[3] Ibid. (1939) p. 468.

[4] Hauty p. 60. The author states that "continued practice ... (of tasks involving) complex perceptual and motor requirements resembling those of skilled work ... results in a gradual rate of decrement" (ibid.).

[5] Seashore (1942) p. 282 f.

[6] Siddal p. 163. The author demonstrated that interesting heterogeneous tasks like tracking may deteriorate during continuous performance in the absence of varied sensory output (p. 163 f., cf. Heron (1957) p. 53 ff.).

[7] Bartley (1942) p. 374.

and what one ought to attend to".[8] The 'wants', consisting of favourable attitudes, pleasant memories and thoughts, need to be inhibited in favour of 'oughts', the compulsory continuation of the task. In this dilemma, when the mind is drawn towards more pleasant memories and objects, the necessary concentration of attention on the performance of the 'oughts' needs "frequently ... greater effort".[9] The compulsory expenditure of additional effort is for the "repression of distracting stimuli arising from the activity of unfatigued mechanisms and natural impulses. As a result, dissatisfaction (is) caused not only by the thwarting of natural inclinations, but also by the repeated inhibition of contrary desires and tendencies".[1] It is a situation, where one becomes inclined to run away from the task which seems to be "intolerable".[2] Under these circumstances "the strain or stress in performing an unpleasant or distasteful job"[3] on the one hand eventually weakens effortfulness of performance and on the other brings about attentional drift, both factors having an obvious influence on objective output.

Feelings of "fatigue" and output decrement

Intimately related to boredom are of course different feelings of "fatigue". As we have seen already Thorndike talked about "bodily pain and strain", "sensory pain" and the like. Other authors mention "fatigue sensation"[4] or "sensory impulses arising in the muscle itself".[5] Sometimes however, a clear distinction is not made between the inhibitory feedback mechanism, rooted in the changes that take place in the muscle and going on in a comparatively automatic way, and the consequences of the conscious sensations.[6] But in other cases the subjective experience

[8] Poffenberger (1942) p. 186.

[9] Dockery p. 340.

[1] Wyatt (1929) p. 3, Bartley (1942) p. 374.

[2] Lewin (1938) p. 284. Barmack (1937) states that during continuous performance "mental block (is the result of) a motivated shift of attention from the work ... and ... a means of temporarily escaping from an unpleasent task" (p. 79).

[3] Ryan (1953) p. 109.

[4] Otani p. 276.

[5] Woodworth (1955) p. 802, Mathews p. 52, Seffarth p. 46.

[6] Osgood (1953) p. 338 f.

of the state of boredom is referred to, for instance as a "desire to stop the action on a conscious level".[7] The role of all these components in a diffuse "fatigue" feeling is important in relation to performance output changes, for these feelings have much to do with "the curve of our ordinary, practical efficiency—of what we actually accomplish".[8] Taylor[9] indeed regarded feelings of tiredness as "largely determined by pre-experimental attitudes rather than by the nature of work itself". But his conclusions are based on wrong experimental procedure. The experimental task was not strictly continuous, on the contrary it was a problem-solving situation of conducting metal slugs through a maze. The author also failed to analyse the nature of variations in feeling tone in relation to performance output changes.

Thorndike once gave evidence for the statement, that feelings of tiredness are not correlated with changes in the real capacity for work.[1] But this conclusion is valid only when the experimentees are forced to continue their work in spite of feelings of tiredness. Thorndike admitted therefore that "in ordinary life the relation is presumably closer, since the common response to such feelings at a certain intensity is to intermit work or stop it altogether".[2] He also says that "stopping the work outright does not of course occur in the great majority of experimental investigations of fatigue, but is very common in ordinary mental work".[3]

There are in fact many experimental results which indicate a positive correlation between feelings of tiredness and output decrement. Poffenberger's[4] investigations of the effects of continuous physical and mental task performances on individual subjects proved "that those who show the greatest falling off in output also show the greatest change in the feelings, and those who show the least falling off in output also show the least change in the feelings". Arai and others came to the same con-

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[7] Schwab (1951) p. 134. cf. Kimber p. 216 f.

[8] Marsh p. 92.

[9] Taylor (1936) p. 816.

[1] Thorndike (1926) p. 104 ff.

[2] Ibid. p. 106.

[3] Ibid. p. 124 f., cf. Robinson (1934) p. 601, Muscio (1921 a) p. 158 f.

[4] Poffenberger (1928) p. 467.

clusion.[5] While most investigations indicate a positive relative relationship between performance output and feelings of satisfaction, a number of industrial studies in fact report contradictory results. Triandes[6] states that a "sample of the publications in this area reveals that some studies obtained positive, some negative, and some no relationship between the two variables". But the contradictory results in the reported studies can be due to a difference between work under more "actual" and under forced conditions and also to the failure to attempt an analytical penetration of all the interacting variables between performance output and feelings of satisfaction.[7] For achieving an optimal level of output the situation would necessarily demand a harmonious and effective adjustment of the two important variables.[8] The optimal output does not merely depend upon the favourable attitudes of the subject to his task or his superiors,[9] but also upon the performance content, the degree of freedom from task interference, variations in techniques of production, the tools and equipment in use, and the nature of involved productive processes.[1] On the other hand the feeling of satisfaction, ranging from "extreme dissatisfaction and discontent to enjoyment"[2] and complete satisfaction, is similarly dependent upon "the type of work in which the individual is engaged, the conditions under which he works . . . his ability to adjust (himself) to the work situation"[3] and the "incentive differences arising from social, familial and economic

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[5] Arai in her classic investigations found that "the average time taken to memorize a german word is 15.7 sec. ... when the subject felt 'good', ... 16.9 sec. ... when the subject felt 'medium' and 18.8 sec. ... when the subject felt 'tired' " (p. 75). In the mental multiplication of a 3 figure by a 3 figure number the time taken on an average was found to be 138.8 sec. when the subject felt 'good', 142.9 sec. when the subject felt 'medium' and 151.3 sec when 'tired' (ibid. pp. 76–77).

Huxtable, repeating Arai's experiment with three subjects in a four-day fatigue series, confirms the findings (p. 15 ff.).

[6] Triandes p. 309.

[7] Kates p. 29.

[8] Heron (1952) p. 78 ff., Crow (1951) p. 338 ff., Foa (1960) p. 9. (1956) p. 475 ff.

[9] Kennedy (1958) p. 375.

[1] Heron (1952) p. 79 f.

[2] Crow (1951) p. 343.

[3] Crow (1951) p. 344, cf. Heron (1952) p. 81 ff., Mulder p. 219 f.

pressures".[4] Important as these intervening variables are in the effectiveness of the dynamic interacting processes of adjustment, "it is not possible to disentangle them before the worker can register his variations: as a consequence the range of these variations within (the individual and the group) tends to appear in the criterion measure in an attenuated form".[5] When all these factors are taken into consideration there is no difficulty in understanding that the correspondence between feelings of "fatigue" and output decrement can sometimes be less evident.

One ought not to look at the relation, however, as only direct or immediate. This is probably too simple an explanation, because feelings of dissatisfaction may partly be a product of diminishing performance output. The subject who is engaged in continuous task performance becomes less motivated, gets into a state of motivational conflict, and suffers from eye-strain, intellectual nausea and other similar discomforts. But when output then decreases he also suffers, because the answers to the given task he is engaged in fail to be as good as earlier. The loss in productive efficiency or reduced output itself may successively bring about increased dissatisfaction.[6] There is in other words an accumulation process, but in the opposite direction to the above-mentioned "warming-up".

The physiological correlates of unpleasant feelings in the state of boredom are rather involved and complicated.[7] But it is in agreement with the former analysis, that "unpleasantness is the conscious state where there is a ... conflict between two or more reactions and a withdrawal from the stimulus".[8] From this point of view unpleasantness is perhaps a sensory process that either does not "contribute to the current development in the cerebrum" or "that interferes with (the) development"[9] of the phase sequence involved in the psychological processes of task performance. Competing reactions in the case of conflict create

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[4] Heron (1952) p. 81.

[5] Ibid.

[6] Robinson (1934) p. 600 f.

[7] Cf. for instance Barmack (1937) p. 68 f., and Mcdowell p. 415.

[8] Langfeld p. 346.

[9] Hebb (1949) p. 232.

conditions of unpleasantness, because they bring about "deterioration in the assembly".[1]

The unpleasantness may however sometimes take an acute form, a state of depressed feeling. We come across the phenomenon in skilled activities characterized by patterns of behaviour involving adjustment and manipulation in diverse coordinated movements.[2] Experimental evidence regarding how skilled acts are effected during continuous performance is unfortunately limited[3] as the problem attracted attention only in rather recent times. Davis,[4] in his extensive experiments in the Cambridge cock-pit,[5] was able to provide test conditions under which the subject had to carry out a *prolonged* skilled performance and which therefore involved a "conflict situation" or in a situation of increased anticipatory tension.[6] Under these conditions he observed that "errors became more frequent and were over-corrected; activity became excessive; movements of the controls tended to be too extensive, and there was a large increase in restless and inappropriate movements. Attention was distributed irregularly over the work and was held by aspects which had acquired a temporary urgency".[7] On the subjective side the situation found expression in emotional disturbance. The subjects were "dissatisfied and irritable. - - - Signs of emotion such as agitation and restlessness were observed, and there was indication that muscular tonus increased. Flushing of the face was common and visible, sweating also occurred".[8] These emotional disturbances are closely related to anxiety, due to the difficulty

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[1] Ibid. p. 225.

[2] Bartlett (1951 a) p. 211 ff., (1951) p. 630 f., Davis (1949) p. 3 f.

[3] Davis (1946) p. 24 f.

[4] Davis (1948) p. 22 ff., (1947) p. 43 ff., (1946) p. 22 ff., (1946 a) p. 119 ff.

[5] The Cambridge cockpit is an experimental apparatus which offers the necessary means for a detailed analysis of the prolonged performance of task processes involved in skilled instrumental flying by trained pilots. The apparatus makes it possible to obtain detailed graphic records of a pilot's instrumental movement, control, adjustment etc. (Davis (1947) p. 44 f., (1946) p. 23). For a detailed pictorial description of the apparatus see Davis (1949) p. 4 f.

[6] Davis (1946) p. 28.

[7] Davis (1946) p. 29, (1949) p. 22 ff.

[8] Davis (1946) p. 29, (1949) p. 25 f., Heron (1957) p. 56.

experienced by the subjects "in attaining a satisfactory standard of performance".[9] Anxiety is associated with the subject's anticipation of or preparation for success during task performance.[1] When the means to achieve success or avoid failure which could relieve the tension are absent, anxiety reactions present themselves. Davis[2] states that "the peaks in the incidence of errors corresponded to the times at which emotional stress was likely to be at its highest". In addition independent interviews conducted by the author among psychiatric patients confirmed the view that "disorganisation of skill was not determined primarily by the prolongation of test, but was due mainly to the anxiety provoked by the (prolonged) test (and) to the difficulty experienced by predisposed subjects in attaining a satisfactory standard of performance".[3] The anxiety reactions express themselves in two ways. Sometimes there is "excessive activity of a restless and agitated kind, excitement, and irritability",[4] i.e. the over-activity reaction resembling the acute anxiety reaction[5] usually understood as the "excitatory type"[6] in laboratory studies on experimental neurosis. At other times the subject's emotional disturbance is associated with "inadequacy of activity, apathy, and discouragement",[7] the state resembling "inhibitory" or "withdrawal reactions",[8] which takes various forms of "'hysteria' ... 'fatigue syndrome' or 'depression'",[9] the tests revealing "a more general reaction comprising frankly neurotic features".[1] In short it seems proper to conclude from Davis' experiments, that they demonstrate in their special way a similar feedback mechanism to that in boredom with its "fatigue" feelings. There was emotional stress resulting in errors, these in their turn caused anxiety with

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[9] Davis (1947) p. 45.

[1] Ibid. (1948) p. 22.

[2] Davis (1947) p. 45.

[3] Ibid.

[4] Davis (1946 a) p. 119.

[5] Ibid. p. 124. Cf. Mowrer (1939) regards heightened expectancy as the cause of anxiety (p. 562 f.).

[6] Davis (1946 a) p. 119.

[7] Ibid.

[8] Ibid. p. 124.

[9] Ibid. p. 119, cf. Davis (1949) p. 27.

[1] Davis (1946 a) p. 124, cf. (1947) p. 45, and (1958 a) p. 236 f.

its different symptoms, and finally this anxiety gave rise to disorganized performance which sometimes ended in passivity or withdrawal from the task.

Monotony and boredom

There is evidence for the opinion that extreme boredom, as in Davis' case with a task involving emotional stress, can often result in depression and neurotic features.[2] On the other hand strong "fatigue" feelings in a neurotic person can be used as a means of helping his own maladjustment.[3] A seemingly existing state of boredom, which can come very easily, helps the individual to withdraw from work which he does not like and consequently wants to finish as soon as possible.

But more interesting than these pathological relationships between motivational states and output is the analysis of monotony. It is in fact difficult to see any great difference between the state of monotony and that of boredom which expresses itself during continuous task performance. Gray[4] made no distinction between monotony and boredom because of the inherent "conflict situation which the workman himself designates by both terms- boring and monotonous". Monotony, a feature of repeated prolonged task processes of performance, generally common in large scale industry,[5] literally "suggests uniformity, changeless-

[2] The "modern large scale and highly organized industry has to face up to a lot of human problems" says Bartlett (1951 a) because "the body and mind are set to work under circumstances with which they cannot deal without impairment of the activity that is demanded" (pp. 216–217). A woeful want of adjustment associated with disorganisation of task processes of performance may lead to "the growth of simmering or open dissatisfaction (which) produce a crop of nervous and mental disorders" (ibid. p. 216, Davies (1926) p. 475).

[3] "Chronic fatigue appears in its most blatant form ... exclusively as the expression of personality maladjustment featuring aimless drifting, monotony, boredom, chronic futility feelings" (Muncie p. 285, Sjöstrand (1949) p. 31 ff.).

[4] Gray p. 248.

[5] Wyatt (1937) having interviewed 355 workers widely distributed in various parts of the country, in "fairly simple forms of repetitive work" found only "3 % of the workers ... practically free from boredom" and the rest were affected by from slight to severe degrees of boredom (p. 3 ff.).

Benedict (1909) reported in continuous performance on a bicycle ergometer that all his subjects "complained of the monotony" (p. 34).

ness, lack of variety, drabness, absence of stimuli of any kind".[6] As a result there is a progressive tendency towards disinclination to continue the task performance because "on the one hand, there is a tendency in activity towards variety (the avoidance of repetition) and, on the other, there is a tendency towards slowing down of activity as it is prolonged".[7] The psychological behaviour involved in the avoidance of frequent repetition of the same stimulus on the one hand and a craving for as much variety as possible on the other, is simply a problem of motivation[8] in reference to the satisfaction of psychological needs. The inadequacy of the inner motivating stimuli in the absence of change and variability leads to performance deterioration and consequent fall in output.[9]

The diminution in the original motivation consequent on monotonous task performance may also be put in relation to the shifting activation level in the sleep—waking continuum.[1] There are many physiological factors which serve as relevant stimuli in varying degrees in this continuum,[2] although experimental measurements have only shown very small changes in these

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[6] Cathacart p. 31, cf. Poffenberger (1942) p. 185 ff.

[7] Bartley (1951) p. 319, Tiffin p. 436, Roethlisberger p. 127.

[8] Hebb (1958) p. 151. In a tapping experiment Warren (1937) found "that the subject was not motivated to work beyond a congenial pace" (p. 104).

[9] Schwellenbach, studying 9,275 men engaged in different operations on the various parts of a battleship, observed that when "the work was not routinized, repetitive, or monotonous (but) permitted the use of individual initiative and resourcefulness ... workers found it possible to maintain the same hourly efficiency under the 10-hour day and 58-hour week as they had under 7½-hour day and 45-hour week" (p. 25). On the other hand in another group engaged in "light operations all operator-paced, and generally consisting of repetitive, monotonous types of work, the general result of increasing daily hours when no other factors were introduced to distort the comparison appears to have been a drop in efficiency" (ibid.).

Extensive experimental investigations in prolonged performance by Arai p. 86 ff., Huxtable p. 8 f., Bills (1936) p. 345, Wyatt (1932) p. 47 f., Adams (1956) p. 208, Broadbent (1953 a) p. 332 ff., (1958) p. 134 ff., Macworth (1950) p. 79 ff., Bakan (1957) p. 410, Payne (1957) p. 4, and Siddal p. 164 f., have demonstrated that it results in loss of vigilance and attention and consequent fall in output.

[1] Kleitman (1939) p. 509, (1957) p. 355.

[2] Barmack (1938) p. 125 f., (1937) p. 69 f., Davis (1955) p. 69.

factors.[3] Diminished motivation in monotony includes, however, not only the rapid abolition of the original need—drive state consequent on the monotonous task, but also following this a decrease of the activation level due to diminished sensory input,[4] until a state of sleep or a more or less complete loss of activation may follow. But just as there is also a process of accumulation in falling to sleep the diminished activation level results in decreased motor activity, "which at once means a decrease in sensory stimulation"[5]—we have a similar accumulation in monotony. The diminished motivation with its consequent decreased activation level is followed by a lower level of efferent stimulation, which in its turn gives rise to less sensory input.[6] In this connection we may also consider the growing influence from the diminution of the performance which all the time contributes to the afferent stimulation. Of course the same point of view can be applied to reactive and conditioned inhibition in relation to the performance of a monotonous task.[7] When we have a state of reactive, and perhaps also conditioned inhibition, it naturally involves a lowered level of activation and a consequent accumulation process in the manner just mentioned.

Boredom, monotony and variation

It follows from the preceding paragraphs that a relevant condition for avoiding decreased output during continuous work is some variation which will balance the diminished motivation during the period of performance. We have already referred above to a number of experiments which offer proof of the validity of this point of view.[8] But what is of interest is the totality of circumstances which can throw light upon variation of behaviour, more especially as a consequence of the organism's own trials to deal with its shifting need-drive state. This is of course only another version of the same problem.

[3] Guyton p. 639, Tyler (1947 a) p. 218.

[4] Bexton p. 71 f., Kleitman (1928) p. 390. See also the experimental investigations of Bakan (1955) p. 390, Wilkinson p. 39, Pavlov (1928) p. 258 ff., and sensory deprivation by Solomon (1961).

[5] Hebb (1949) p. 219.

[6] Dureman p. 19 ff.

[7] See pp. 84–85.

[8] Cf. for instance pp. 82–83.

One may in this connection remember Hull's concept of "behavioural oscillation",[9] for at the bottom of the variations of the reaction potential ($_sE_r$), there is possibly a variation of drive (D). But unfortunately the author also fails to explain the psychological factors involved in the whole problem. More elucidating are the experiments with massed and distributed practice. While distributed practice may be more advantageous[1] than massed practice, the nature of spacing needs consideration.[2] In the studies of distributed practice the temporal spacing, i.e. the duration of either the practice period or the rest period or both, is varied. During continued task performance the sequence of responses are varied and perhaps the number of stimulus presentations too. The effects of change of duration of either the work period or the rest period on the performance output is additive, meaning "that a given amount of variation in the duration of the one can be balanced by a corresponding variation in the duration of the other".[3] The performance by itself has little to do with such temporal spacing. If the rest period in distributed practice has a positive influence the response variations may be considered in massed practice. Hauty[4] demonstrated "that as optimal conditions of varied nature are incorporated into the total work situation, work decrement is correspondingly reduced". Solomon's[5] interesting variant of Hull's[6] formulation of negative drive consequent on the response repetition is significant and in line with these findings. Solomon[7] draws our attention to the aspect of the repetition of a "stimulus complex" as the cause of development of negative drive. Although the stimulus complex may also be conceived as being response-produced, nevertheless the emphasis of Solomon's variant of Hull's conception of negative

[9] Hull (1943) p. 304.

[1] Graf p. 898.

[2] Åstrand (1960 a) p. 453. Hick (1948) p. 51.

[3] Gagne (1953) p. 159. Conwell's study of a rotary pursuit task tends to support the notion that the effects of either work or rest on performance output is additive (p. 145, cf. Kimble (1949 a) p. 337, (1949 b) p. 157).

[4] Hauty p. 66, cf. Payne (1957) p. 5.

[5] Solomon (1948) p. 5 f.

[6] Hull (1943) p. 278, (1951) p. 75, (1952) p. 10.

[7] Solomon (1948) p. 5.

drive predicts the possibility of stimulus complex variations which may influence the amount of subjectively experienced effortfulness and so the performance output.[8] This effortfulness in task processes can be brought about in different degrees by stimulus variations during performance. Gagne[9] reports some experiments involving "variations in stimulus complex" and also variations in "amount of effort", but the author makes no attempt to relate the output variations to variations of stimulus complex or "to systematic variations in the effortfulness of the learning task".[1] Real experimental evidence is therefore lacking for a correlation between the variation within the task itself and the output changes in massed practice. But this correlation is at least indicated, and it can perhaps be interpreted in terms of the importance of variation for original motivation during work.

Concerning the tendency of the organism to vary its behaviour we may consider experimental studies on spontaneous alternation by rats during maze running.[2] The response-oriented concepts based on the theories of Hull[3] have not been accepted as the only possible explanation, and the reactive inhibition hypothesis of spontaneous alternation has been met with objections.[4] Glanzer[5] offered the substitute theory based on stimulus satiation according to which the "explanation resides in the effects which exposure to stimuli has on the organism". But the stimulus satiation theory fails to take into consideration several variables which complicate the nature of trials in maze, whether free or forced, rewarded or unrewarded.[6] An increased amount of rats' maze running resulted for instance in no change in the amount of

[8] Gagne (1953) p. 162.

[9] Gagne (1953) p. 159 f.

[1] Ibid. p. 162.

[2] Wingfield (1934) p. 145 f. Similar experiments reported by Dennis (1935) using more units of maze confirm the results, and a rat's tendency towards spontaneous alternation behaviour is generalized (p. 490).

[3] Hull (1943) p. 278 f.

[4] Heathers p. 379, cf. Zeaman p. 186, Solomon (1948) p. 5 f., Dember (1958) p. 426, Rice (1957) p. 108.

[5] Glanzer (1953) p. 393. The data on the contradictions of the reactive inhibition hypothesis in explaining spontaneous alternation behaviour are summarized by Glanzer (1953 a) p. 257 f., cf. Estes p. 361.

[6] Thompson (1960) p. 200 f., cf. Jackson (1941) p. 261.

spontaneous alternation.[7] And "increasing the work or effort involved in making the response did not lead to an increase in the tendency to alternate".[8] Rothkopf[9] interpreted alternation behaviour by a type of composite "tired stimuli and tired response" theory. Sometimes alternation has been interpreted merely as "a term rather than a form of behaviour",[1] the scope and nature of the variability mechanism thus being limited to a relatively unimportant role. This, however, is certainly going too far. Sutherland for instance states that "spontaneous alternation and exploratory activity are basically the same phenomena".[2] At least the exposure of the human organism to a stimulus complex and the consequently varied behaviour probably need to be considered in relation to the drive state and the purpose or performance goal.[3]

In any case behaviour variability may be in some degree a need for the organism for its "survival value in the evolutionary sense".[4] Trial and error is a necessity for an organism without ready-made solutions for getting need-drive satisfaction. Whatever its place in the learning process is—however "blind" or "directed" it is considered to be[5]—there is agreement upon its relation to the motivational state. The behaviour will be varied as long as dissatisfaction is still present. Variation is an answer to an annoying state, and it may therefore seem natural to provide it, when work has caused annoyance.

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[7] Dennis (1939) p. 310 f.

[8] Walker (1955 a) p. 85.

[9] Rothkopf p. 255.

[1] Burack (1950) p. 21, cf. Galanter p. 18, Walker (1955) p. 22.

[2] Sutherland p. 361.

[3] Walker (1955 b) p. 27, cf. Glanzer (1953 a) p. 261 f.

[4] Lepley p. 24, cf. Harlow (1949) p. 59, Krechevsky (1937 a) p. 158, (1937) p. 123 ff.

Heron (1957), citing the remarkable account of a solitary prisoner, states that "variety is not the spice of life: it is the very stuff of it" (p. 56).

[5] Woodworth (1955) p. 823 f., (1945) p. 776 f., Vandegeer p. 45 ff., Duncker p. 17 ff., Durkin p. 83 f., Leeper (1935) p. 38, Claparade p. 61 ff., Maier (1929) p. 88 f., (1930) p. 300 ff., 115 ff., (1930 a) p. 133, (1931) p. 191 f., (1938) p. 39 ff., (1938 a) p. 541 f., (1938 b) p. 77 f., (1940) p. 45 ff., Krechevsky (1932 a) p. 43, (1933) p. 442, and Walker (1955 a) p. 84 f.

The role of attitude and interest in continuous work

A consideration of the role of attitude and interest in output changes may be important. Unfortunately, however, the concepts of attitude and interest are utilized in psychological literature without any scientific distinction.[6] A frequently cited definition of attitude is that of Allport,[7] according to which "an attitude is a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related". Sargent[8] explained the ambiguity and confusion involved in this definition. He says that "an attitude defines one's position, towards a given aspect of his perceptual world".[9] As implied in the term "state of readiness" attitudes "are rooted in motivation and emotion and exist as a continual potential toward behaviour".[1] At the same time "attitudes are integrated into an organized system, although this does not exclude the possibility of contradictions in the totality of attitudes and opinions. ——— They are also close to the core of personality ... They are relatively persistent and enduring ——— yet (they) are subject to change".[2] The definition is all-inclusive and Vernon[3] considered that "interests are very much the same as attitudes". In view of the confusion in the definition of the terms, a clarification of the two concepts may be advantageous before considering them as factors influencing performance output variations.

Psychologists differ in their opinions regarding the definition of the term attitude and also in the description of the psychological processes involved in the formation and expression of

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[6] Blair p. 192, Greene (1952) p. 594.

[7] Allport (1935) p. 810.

[8] Sargent p. 225 f.

[9] Ibid. p. 225.

[1] Ibid. p. 226.

[2] Ibid.

[3] Vernon (1953) p. 161, Kornhauser p. 71, Arnaldi p. 5. Thorndike (1935) in his work (p. 160 ff.) "uses the words ... interests and attitudes for most of the time in the same breath without any explicit differentiation" (Berlyne (1949) p. 186). It may be noted that in the discussion on warming-up (pp. 93–95 the author uses "attitude" in the same sense as "interest" according to the distinction made in the following pages.

attitudes.[4] Crow's[5] consideration of interest as a motivating force that stimulates an individual to participate in one activity and not in another[6] implies an involved selective process of taking part in the particular activity. Newcomb[7] recognized attitude to be "like a motive". But he made a distinction between the direction of behaviour and the actual behaviour as such. On the basis of this difference he considered motive arousal to be temporary, appearing, disappearing, and reappearing as a state of drive, while he considered attitude to be more specific, persisting and stable. His distinction of motive as goal-directed and attitude as subject-centered is however, not clear. The ambiguity in the definition persists. As in most discussions of attitudes there is confusion in distinguishing the readiness for motive arousal[8] and the affective properties assumed to be charged in attitudes.[9] According to Peak[1] attitude is a "hypothetical construct" depending upon two variables. One refers to affective property which means that "the affective loading of any act or concept will be a factor in determining the probability of its arousal".[2] The liking, choice value or preference is essentially the same as reinforcement value. The other is the instrument value or the degree of probability that certain behaviour will lead to an outcome which may be considered similar to an expectancy construct.[3] Peak[4] denied that attitude is "readiness for action" and recognized that attitude does not account for the persistence and intensity of behaviour. While denying that attitude is essentially behavioural in construct, however, she considers it to be a component of motive structure.

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[4] Sherif (1946) p. 1 ff., (1945) p. 295 ff., Krech p. 152, Doob p. 136 ff., Cattel (1949) p. 81 ff., (1947) p. 222 f.

[5] Crow (1956) p. 201 f.

[6] Ibid.

[7] Newcomb p. 119.

[8] Stagner p. 2 ff.

[9] Kornhauser p. 71, cf. Krech p. 152.

[1] Peak p. 151.

[2] Ibid. p. 183.

[3] Ibid. p. 151 f.

[4] Ibid. p. 152.

Birney[5] experimentally attempted a distinction between motive and attitude. His conclusions are well expressed by Vogel:[6] "Whether a need will be expressed in fantasy, in behaviour, or not at all, is a function of the regulating process in the personality". The distinction then would appear to be "between motives (as) instigating processes and attitudes (as) regulating processes"[7] in which case attitude would remain in the same area as motivation. All this confusion appears to lie in the failure to recognize a distinction between a state of one's actual concern with a situation and the other purely imaginary or attitudinal state. Guilford[8] defines attitude as a disposition to "favor or not to favor a type of social object or social action" and understands interest in terms of the dynamics of arousal or 'instigator', thus placing it "in the general area of motivation".[9] He offers, however, no experimental verification for such a distinction. Sjöstrand's[1] recent work in this direction throws interesting light on the contradictions and confusions of the two concepts and attempts to break the deadlock. He attempts logically and experimentally[2] to define the concepts by taking into consideration the necessary part of the cognitive representations[3] of the organism's motivational states according to the model need-drive-action-relaxation. From this point of view attitude has nothing to do with the organism's activity or its actual motivational state, while interests are always coupled with an active participation in pertinent activities.[4] Thus he says that "interest and action should, as a rule, be concomitant but not attitude and activity".[5] He does not mean, however, that attitude has no place in motivation psychology. Attitude is conceived "quite simply as . . . cognitive processes independent of the drive components functioning

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[5] Birney p. 134 f.

[6] Vogel p. 111.

[7] Vinacke (1960) p. 266.

[8] Guilford p. 223.

[9] Ibid. p. 205.

[1] Sjöstrand (1958) p. 233 ff.

[2] Ibid. (1960) p. 309 ff.

[3] Klein p. 89 f.

[4] Cf. Scheerer p. 121.

[5] Sjöstrand (1958) p. 242.

at the moment".[6] From this point of view attitude may help in gaining valuable information concerning affective properties of a task performance in predictions of behaviour. Thus if determinations of an attitude indicate that a certain attitude towards a task is not satisfactory, attempts may be made to direct and canalize the subject's motives by stimulating basic drives which may lead to the desired conduct.[7] But interest is to be understood as cognitive anticipations of the different already known actions and their consequences for the organism in connection with its actual motivational state.[8] It will therefore have an immediate influence upon the direction of the activity as long as the motivational state is in existence. With this distinction between interest and attitude it is easier to consider its role in performance output changes. During task performance the organism is thrown into activity. The disequilibrium consequent on the drive state is associated with those cycles or phases of behaviour that need to be sequentially canalized in a persistent and directed fashion if the drive state is to be abolished.[9] Interest may in this connection be conceived as the anticipatory mechanism having a "drive regulating role".[1] It regulates the organism's activity in accordance with experience of its consequences for the satisfaction of the drive itself. When a drive decreases the relevant interest decreases too. But the attitude is not effectively changed.

From such a conceptual distinction one can understand the function of interest in continued work. As long as the drive tends to increase, the interest will direct the activity into the same channels and up to that level. But with decreasing drive the interest weakens, and a new one may appear and direct the activity to other goals. Only if one cannot follow this actual trend would situations arise for negative experiences, which can in their turn influence the permanent attitude.

[6] Ibid.

[7] Roethlisberger reported an experiment where the study of the operator's attitude lead him to make a change in the task environment after which he obtained increased performance output (p. 185 f., 329 ff.).

[8] Sjöstrand (1958) p. 241 f.

[9] Shaffer p. 89, cf. Symonds p. 24 f.

[1] Sjöstrand (1958) p. 243.

Conclusion

From what has been shown in this chapter it follows that changes in output during continuous work are not very much dependent upon motivational processes. Decrement of output is therefore to some extent a consequence of a decrement of the original drive during work.

PART II

EXPERIMENTAL CONTRIBUTIONS

CHAPTER VI

OWN EXPERIMENTS

"Slöjd" and Mental Tasks of Different Complexity

For the purposes of experimental elucidation of the nature and scope of output changes during a two hour period of continuous moderate work, it would be necessary to select suitable forms of work. In this connection "slöjd" (wood work) with its varied and complex aspects answers the required conditions in India because it is also one of the basic crafts[1] utilized as the media of education in Basic schools. Mental tasks in their turn may vary in content and in degree of complexity. But continuous arithmetic work is not very varied and complex and would therefore present a good contrast to continuous "slöjd" performance.

"Slöjd" performance with its varied content provides a diverse class of problem situations[2] and scope for a wide range of stimulus and response variability. The problem situation appeals to dif-

[1] Spinning and weaving, and agriculture and gardening, are the other two basic crafts in Indian basic schools (Ministry of Education (1956 a) p. 61 ff.).

[2] Duncan (1959) p. 425. The author makes a thorough uptodate review of human problem solving.

Opinions among psychologists vary on "what constitutes a problem" (Saugstad (1955) p. 191, Brownell p. 416, Russel (1956 a) p. 252). Dewey's five steps of thinking (Dewey (1910) p. 72, (1935) p. 176) appear to have influenced a number of subsequent works in problem solving (Gray (1935) p. 353 f., Johnson (1944) p. 202, Polya p. 5, Bloom p. 25, Burack p. 24, Vinacke (1952) p. 161, Gyr p. 39). Disputing this Thorndike (1950) stated that "there is no simple pattern or routine of problem solving which can be isolated and taught in the schools as a simple unitary skill" (p. 215, cf. Heidbreder p. 540).

However it is generally agreed that a problem situation obscures the goal solution the phases of which need to be appraised and investigated (Whitefield p. 184, Bales (1951) p. 494, Duncker (1939) p. 176 ff., Saugstad (1958) p. 384 ff., (1957) p. 276 f., (1959) p. 57 f.).

ferent secondary needs and the behaviour variability tends to "neutralize or retard the onset of boredom,[3] at the same time keeping the activity drive[4] alive as long as possible. This performance situation also offers opportunity for group activity, involving social drives derived "partly from the coordination of the acts of several performers into one harmonious and well directed action, partly from the spirit of rivalry that may be engendered between groups".[5]

Performance under these conditions may of course be interesting and the stimulation of different sense organs with the changing environmental conditions involved in the interplay and coordination of activities releases likewise a constant stream of impulses from the various sense organs to the cortex[7] which effect a state of wakefulness,[8] thus tending towards the maintenance of a state of optimal arousal.[9]

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[3] Wyatt (1928) p. 24, cf. Lewin (1928) p. 153 ff.

[4] The main drives involved are exploratory drive (Montgomery (1952 a) p. 56 f., (1953 b) p. 133, (1951 a) p. 587, (1952) p. 292 f., Barnett p. 289 ff.), and manipulatory drive (Carr (1959 a) p. 248, (1959) p. 123 f., Miles (1958) p. 41, Myers (1954) p. 453). However, distinctions are made between activity drive, exploratory drive, manipulatory drive (Butler (1953) p. 98, (1954 a) p. 23, Montgomery (1953 a) p. 441, (1953) p. 318, (1955) p. 132, Hill (1956 a) p. 18), homogeneity drive, boredom drive etc. (Symmes p. 196). But Dell (1958) states that it is superflous to assume that these several drives are independent of each other and considers them in the unitary sense of nonspecific behavioural state (p. 200).

[5] Woodworth (1918) p. 202 ff. A wide range of experiments have demonstrated that group activity arousing interest and attention has therapeutic value for the patients because "day dreaming and morbid introspection may be replaced by outwardly directed interest and a feeling of accomplishment" (Jones (1960) p. 67, (1957) p. 211 ff., (1956) p. 647 ff., (1956 a) p. 985 f., (1956 b) p. 343 f., (1952) p. 53 ff., Baker (1956) p. 278 f.).

Sivadan draws particular attention to the complexity of the work, the nature of the raw material used, and the quality of social interaction involved, and attempts to grade these factors according to the degree of regression manifested by selected patient groups (p. 207 f.).

[7] Kleitman (1929) p. 656 f., cf. Bexton p. 70. Gibson (1958) p. 193, Davis (1960) p. 890 f.

[8] Lindsley p. 514.

The studies of the reticular formation of the brain indicate that it regulates brain activity through arousal reaction which in turn depends on the constancy of sensory bombardment. Sensory stimuli in maintaining arousal rapidly lose their power to do so if they are restricted to the monotonous repeated stimu-

"Slöjd" performance seems in this way to maintain the activity in its own right.[1] In addition an adequate "accomplishment of

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lation of an unchanging environment (Olds (1956) p. 107 ff., Hebb (1958) p. 172 ff., Vernon (1957) p. 105, Wang p. 130 and Sensory deprivation by Solomon (1961)).

[9] French p. 588.

Sharpless distinguished two types of arousal pattern, tonic and phasic (p. 674 f.), though Cobb summarizing previous work and offering evidence wrote "tonic and phasic reflexes though unlike, are separated by no fundamental difference in physiological mechanism" (p. 543).

The tonic reaction is referred to the BSRF system whose "reaction varies in duration from a few seconds, to many minutes, has a long latent period following the stimulus, is subject to rapid habituation, and tends to recover slowly over periods of hours or days" (Samuels p. 3). However Granit (1957) refers to a pattern of "separate indirect tonic motor system run from the gamma fibres" (as essentially different from the alphas in conduction velocity) (p. 68, cf. ibid. (1957 a) p. 1919 f.). This gamma system needs serious attention "particularly when tonic types of movement are discussed (as it) is probably the most sensitive indicator we possess of what in present-day brain physiology is called 'activation' assumed to arise in the brain stem" (ibid. (1957) p. 73). The "gamma activity is truly tonic and persistent, never resting, except when actively inhibited" (ibid. p. 67). Granit (1953) offers evidence "that the gamma system is well provided with diffuse central connexions" (p. 157), and properly setting the gammas, "the mechanism ... according to its needs, can avail itself of the full range of dynamic sensitivity of the spindles, different for slow and fast acts, different again for coarse and delicate movements and also largely independent of muscle action" (Granit (1956) p. 365, (1957) p. 68).

The phasic reaction is referred to the diffuse thalamic system. "It rarely outlasts the stimulus by more than 10 or 15 sec, has a short latency, is very resistant to habituation and once habituated recovers within a few minutes" (Samuels pp. 3–4). This peculiar characteristic of phasic reaction in resisting adaptation to continued stimulus during task performance is significant in that "the arousal mediated by the thalamic nuclei (though) of short duration mediate a more differentiated attentional state to a stimulus after the first gross arousal induced by BSRF had adapted out" (ibid. p. 4).

[1] Veblen p. 31 f. Hebb (1955) reports a pedagogical experiment where "600 odd pupils in a city school, ranging from 6 to 15 years of age, were suddenly informed that they need do no work whatever unless they wanted to, that punishment for being noisy and interrupting other's work was to be sent to the play-ground to play, and the reward for being good was to be allowed to do more work. In these circumstances, all of the pupils discovered within a day or two that within limits they preferred work to no work (and incidentally learned more arithmetic and so forth than in previous years)" (p. 246).

(task) is a source of gratification".[2] The problems that mediate the task processes of performance are on the other hand coloured by partial difficulties involving some risk and frustration. And such occurrences containing an element of thrill would intensify the problem situation and contribute to activation.[3] This activa-

[2] Veblen p. 32, cf. Kabir p. 27.

[3] Hebb (1949) p. 233. Woodworth (1952) refers to "escape motives" (p. 310) and "empathy" (p. 340) in play and activity and the resulting joy and psychological satisfaction from risk and fear present in such activities. Valentine observes similar tendencies in children (p. 416 f.).

Brown (1949 a) demonstrated that fear and frustration "function as a drive to motivate or energize behaviour" (p. 758) and thus emphasized the importance of positive forms of risk-taking or mild fear and of problem-solving or mild frustation in performance (Berlyne (1950) p. 72, McLelland p. 318 ff., Atkinson (1958) p. 333 ff., (1957) p. 371, Whiting (1943) p. 229 ff.). Such forms of behaviour in relation to the point of arousal which makes organized cortical activity possible (Hebb (1955) p. 250) has relevance to Duffy's (1951) concept of the "degree of energy mobilization" (p. 34, ibid. (1941) p. 285 f.), and Lindsley's (1951) "activation theory of emotion" for strength of behaviour (p. 504 f.).

The conditions that determine the nature of arousal at a given time in behaviour continuum are still obscure and complex. The Hull's (1943) school with its conception of 'general drive state' (p. 300 f.), came close to the principle of arousal, but "activation does not fit very well into s–r formula (as) it is a phenomena of slow changes, of drifts in level with a time order of minutes (even hours) not of seconds or fractions thereof" (Malmo (1959) p. 384). The evidence of behavioural arousal provided by Duffy (1932) p. 544 f., (1951) p. 34, (1957) p. 267 f., Freeman (1948) p. 223, (1938 a) p. 149 f., (1933) p. 45 and others of the 'energetic group', Bills (1937 a) p. 286 ff., Courts p. 255 f., Stauffacher p. 43 f., indicates the existence of such a mechanism in the brain. Further the experimental work in degrees of tension and performance by Duffy (1932) p. 544, Freeman (1933) p. 45, Gregg p. 77, Jacobsen (1929) p. 164 ff., Bloom p. 96, Bills (1937 a) 286 ff., and Lovaas p. 151 f., demonstrates that the performance level during a state of arousal is represented by an inverted "U" shaped curve where "over-motivation ... may be conceived of as resulting in part from too high a degree arousal ... represented at one end of the inverted "U" shaped curve", and lack of motivation "during drowsiness or fatigue would be represented at the other end of the curve" (Duffy (1957) p. 268). Stennet p. 60 and Scholsberg p. 87 confirmed the findings. Accordingly an optimal level of arousal or "in general, the optimal degree of 'activation' appears to be a moderate one, the curve which expresses the relationship between activation and quality of performance taking the form of an inverted 'U'." (Duffy (1957) p. 268, Hebb (1958) p. 174, Freeman (1948) p. 223, (1938 a) p. 149 f., Stauffacher p. 43 f., Courts p. 255 f., Pearl p. 202). Hebb (1955) interpreted such a state of

tion during continued task performance helps in the maintenance of the stability and persistence of the sequential processes of performance and hence performance efficiency.

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arousal as a moderate drive level, with a direct provision for cue function (p. 250 f., Harlow (1953) p. 25 f.).

The increasing flow of experimental evidence in EEG and neurophysiology (Larsson (1956) p. 642 ff., (1960) p. 21 f., (1960 a) p. 290 f.), more especially concerning the integrative functions of the Ascending reticular activating system (ARAS) (Lindsley (1957) p. 95 ff.) have made it possible to formulate the more general form of behavioural arousal in terms of the neurophysiological dimensions of arousal as "the continuum extending from deep sleep at the low activation end to 'excited' states at the high activation end (which) is a function of the amount of cortical bombardment by the ARAS, such that the greater the cortical bombardment the higher the activation. The shape of the curve relating level of performance to level of activation is that of an inverted U: from low activation up to a point that is optimal for a given performance or function, level of performance rises monotonically with increasing activation level: but past this optimal point the relation becomes non-monotonic: further increase in activation beyond this point produces fall in performance level, this fall being directly related to the amount of the increase in the level of activation" (Malmo (1959) p. 384). The level of activation at a given time is determined by the nature of the psychological field "involving relations of similarity, opposition, completeness, antecedents and consequents" (Peak (1958) p. 346). Peak (1958) predicted the level of activation in relation to the nature of such psychological structure assuming "a. relation of distance to the probability of activation: b. the combination of probabilities when there is multiple input to the same point in structure: c. the combination of probabilities when parts of structure are arranged serially: d. the number of events that are distinguished within an activation pattern: and e. the development of activity decrement as a result of activity" (p. 346). On this basis Silverman attempted galvanic skin responsivity to venous tone, blood variations etc., to establish psychophysiological relationship and found positive correlations (p. 83 f.). Similarly Schnore's measures in heart rate, blood pressure, respiration rate and right arm muscle tension "consistently differentiated between high and low arousal conditions" (p. 127). Freeman (1959) using an ergometer as indicant of drive attempted to find the duration of behaviour response to food deprivation (p. 1071 f.). These measures undoubtedly provide useful information about emotional states and reliable indicants of arousal. But they fail to indicate clearly the specific nature of their relationship to ARAS and the combined effects of all the various and sundry antecedent conditions which at any moment in time determine the level of drive (Malmo (1958) p. 244 ff.). Attempts to determine "how habituation and learning and how emotional or other stimuli affect the reticular formation, or those cortical and peripheral structures which give rise to impulses which feed into it" (Lindsley (1957) p. 60), may contribute towards the solution of the nature of arousal.

In this manner "slöjd" performance and complex mental tasks involving sensorial and behaviour variability release the individual from boredom and monotony. The original drive is kept at the maximum and the rise of reactive inhibition (I_r) may be checked to a minimum. The sequential performance processes continue with stability and persistence and can result in increased output.[4] Conversely task performance involving less variability is comparatively less satisfying and activating, can give rise to more I_r, and so result in decreased output.

Continuous wood-work and arithmetic calculations

We may now consider the role of "fatigue" in output changes in continuous two-hour mental and physical task performances. A continuous two-hour arithmetic task and a continuous two-hour "slöjd" performance (wood-work), an educational school craft, were the respective mental and physical task performances. I began my experiments in the autumn of 1954 among the 5th grade pupils in the 12-year-old age group in the Uppsala Elementary schools and continued till the end of the 1957 spring term.

The tests

Now during the continuous two-hour performance of arithmetic work and "slöjd", it would appear obvious that the work output and the interest or the feeling states of the pupils in relation to the job are subjected to changes because of the continuity of task processes. These changes may be indicated or express themselves between the tests administered at the beginning and close of the two-hour period of continuous task performance. Therefore it was necessary to frame tests for 1. arithmetic work, 2. "slöjd" perform-

[4] Harlow's (1949) experimental investigations into activity drive indicate improved quality and quantity of output (p. 58 ff., ibid. (1950) p. 234).

Several other experimental studies in social and group activities where children had opportunities to participate in spontaneously organized groups with a liking for their work showed superior quality of performance and significant gain in output (Leonard p. 101 ff., cf. p. 152 f., p. 168 f., Forbes (1943) p. 157, Tipper p. 149, Raab p. 384 ff.).

Experimental investigations in satisfyingness indicate that when performance conditions are satisfying to the individual, a steady working rate is maintained with increasing efficiency giving rise to increased output (Wyatt (1928) p. 24, Warren (1937) p. 104, Walker (1950) p. 54).

ance, and 3. changes in the interest or the feeling states of the subjects which could be administered at the beginning and close of a two-hour period of the respective task performances. The tests would be general output tests for a ten-minute period in arithmetic task and "slöjd" performance. An interest rating scale indicated the varying states of the feeling tone of the subjects engaged in the task performance.

The arithmetic test consisting of mechanical multiplication and division calculations demand sufficient mental effort involved in concentration and application to cross mental processes. Therefore it would be a good mental test to determine the output fluctuation occurring during a two-hour period of continuous mental work. Accordingly two sample lists containing 35 multiplication and division calculations familiar to the pupils were set. In preparing the lists of arithmetical calculations the following points were kept in mind:

1. The number of digits in the multiplier and divisor were limited to 3 as the pupils were not used to working beyond 3 digit calculations. 2. The zero difficulty was included. 3. The multiplication and division calculations were alternated. 4. The division calculations were so set that the remainder could result in zero to facilitate easy scoring. 5. The calculations were placed in order of difficulty. From the two sample lists prepared under the above conditions it was necessary to obtain two new lists of arithmetical calculations of similar type and of equal difficulty that could be used as a ten-minute test before and after the two-hour period of continuous mental work.

Accordingly the two sample lists were given to two groups of 119 pupils in the 5th grade of Uppsala Elementary Schools. A period of half an hour was given to solve the calculations and the pupils were instructed to mark off the number of calculations solved after every 10 minutes. The sample lists were alternated on the following day between the two groups. The number of calculations correctly solved formed the basis of the score. Partial mistakes were considered incorrect and so rejected. The scores are to be seen in table I. The mean difference in scores between the two sample lists is 0.56. Although the arithmetical calculations in the two sample lists are of practically equal difficulty, the distribution in the two classes appeared to be different. This may be due

TABLE I

Arithmetical calculations for different days and groups (mean scores).

	N	M	S. D.
FIRST DAY			
List A	56	20.64	5.66
List B	56	23.07	5.45
SECOND DAY			
List B	57	16.66	5.05
List A	57	17.92	5.16
TOTAL			
List A		19.27	
List B		19.83	Diff. 0.56

TABLE II.

Arithmetical calculations attempted in the three successive 10-minute intervals (mean scores)

LIST A			LIST B		
I	II	III	I	II	III
15.19	6.16	4.19	17.60	6.91	4.00
LIST B			LIST A		
13.15	6.24	3.52	14.49	6.35	3.00

to a difference in the methods of tackling the alternate multiplication and division calculations in the sample lists. Therefore the easiest and the most difficult calculations were eliminated from the sample lists by a process of internal analysis and the division calculations were then placed after the multiplication ones instead of alternating with them. In accordance with the number of calculations solved in each 10-minute interval (table II) 20 arithmetical calculations, 9 multiplication and 11 division were selected out of the two respective sample lists on the conditions indicated. These two final lists of equal difficulty, A and B, formed the 10-minute mental tests at the beginning and close of a two-hour period of continuous mental work.

Similarly a ten-minute physical output test was necessary at the beginning and close of a two-hour period of continuous "slöjd" performance in order to indicate the effects of a continuous two-hour physical task performance. However "it is notoriously more difficult to construct a reliable performance test than to construct a reliable written test".[5] But these difficulties can be avoided, by "letting the behaviour continue for an adequate period of time".[6] From this point of view "slöjd" performance as an educational craft offers genuine scope for devising a reliable performance test. The finished product of performance is not too big and complicated. For devising a miniature performance test "slöjd" performance "offers a number of advantages, such as the use of less cumbersome and more easily duplicated equipment, greater condensation of important work processes within a short testing period, and elimination of risk".[7] Under these circumstances the performance testing situation can be made similar to the actual task performance conditions.[8]

In accordance with these conditions 5 samples of "slöjd" performance tests were attempted with a 5th grade group of 10 pupils who were familiar with the performance of the test samples during their school work. Girls were excluded in the experiments as wood-work in not a part of their regular school work. The following were the samples tried:

	Scale in mm.		
	L.	B.	T.
1. Scale with a row of holes.	300	60	20
2. Key hanger (heart shape).	40	40	3–4
3. Key hanger (rectangular shape).	360	40	10
4. Herring board.	350	120	15
5. Seed-pick. ("Frösticka")	300	40	12

Performance results of the test samples revealed that the time required to produce the different samples varied between 15 and 25 minutes. The production of the first four objects not only required more time, but required more raw material. It also in-

[5] Cockett p. 29.
[6] Cockett p. 36.
[7] Anastasi p. 493.
[8] Berger p. 512.

volved unnecessary duplication of tools and equipment acting as hindrances to a well ordered and quick performance test. On the other hand the last test appeared to possess some advantages. The following were the materials and tools required in the production of the seed-pick ("Frösticka"):

1. Materials: a. Work bench ($32 \times 4.5 \times 12$ mm.) b. Piece of wood.
2. Working tools: a. Jack-plane. b. Small saw. c. File.
3. Accessory tools: a. Hammer. b. Knife. c. Sand paper. d. Set-square. e. Ruler. f. Pencil.

The foregoing indicates that adequate tools and equipment are available for the production of this product, which offers ample scope for the exercise of the psychological functions, as perceptual, spatial and manipulatory agility, during task performance. The performance test closely reproduces the "slöjd" performance conditions in the class room. The quantity of raw material (wood) used during the performance of the sample test being rather small, it would be economically cheap to conduct the experiment on a large number of school pupils. By organizing the performance procedure of the sample test it appeared that the work processes involved in the production of the test sample could be localized and concentrated into a period of 10 minutes.

Accordingly the seed-pick ("Frösticka") performance test was given to two 5th grade classes of 15 pupils each in two different Uppsala Elementary Schools. Eleven teachers from different elementary schools independently classified the test product in order of rank. Evaluation of the rank difference gave a mean rho 0.69. This means there is a relatively great difference in evaluating the test products. These differences are due to the teachers' lack of competency and experience as "slöjd" instructors. Therefore the degree of correctness of judgement involving the size, form, fineness etc., of the sample test product varied from judge to judge. In order to avoid the deficiency it was necessary to get the performance test product scored by three experienced "slöjd" instructors independent of each other on the basis of agreed and prescribed conditions of scoring. According to Anastasi[9] "the scoring of work-samples may be based on either the process, the product,

[9] Anastasi p. 494, cf. Greene (1954) p. 201.

or both. The nature of the task may determine which aspect is scored . . . In many tasks, both process and product are amenable to observation, but the product lends itself more readily to objective scoring." It would seem obvious that the various aspects of the task processes are latent in an integrated and condensed form in the finished test product of performance. Therefore the performance test product may significantly lend itself to objective scoring. Accordingly the performance product was scored in three aspects of the productive processes involving different degrees of difficulty, speed and accuracy of eye-hand coordination and manual dexterity. In the operational processes of the jack-plane 5 sides of the performance product are planed and the performance is weighed between 1 and 9 during scoring in relation to the planing processes of the 5 sides of the finished product. Similarly the sawing processes of the top two sides of the finished product is scored as — 1 to 4 by weighing the performance and lastly the operations of filing and use of sand paper is scored as 1 to 2. The maximal total score of 15 was given to the best finished product and the remaining performance products were scored relative to this. At the same time for the maximum score of 15, the scatter of the performance is large enough for statistical calculations. So the 10-minute seed-pick ("Frösticka") performance test was used at the beginning and close of a continuous two-hour "slöjd" performance.

In regard to the interest or the changing feeling state of the pupils during the continuous two-hour performances a seven degree arbitrary scale ranging from "most unpleasant" to "most pleasant" was constructed. The individual pupils were asked to mark off their feeling tone on the scale in relation to their work, without outside interference, at equal intervals of 20 minutes.

The experiments

With the 10-minute mental and physical tests to be administered before and after the two-hour periods of continuous task performance and the scoring of the feeling tone scale during the two-hour performance, the experiment in continuous task performances covered 113 fifth grade pupils from Uppsala Elementary Schools in four groups. The continuous two-hour mental task

consisted of arithmetical calculations. A large number of exercises in mechanical multiplication and division was at hand sufficient to cover the full length of two hours. Similarly in "slöjd" performance a number of work projects producing wooden spoons, book-stands, boats, bell-towers etc., were preplanned so that their performance would last for a continuous period of two hours. A control group with a two-hour interval of rest instead of work was chosen against the respective mental work and "slöjd" performance groups. The control groups during the period of rest were permitted to look at picture books and indulge in light reading and low conversation. However these activities were comparatively relaxing in their nature. A 10-minute mental test (arithmetical calculations) and a 10-minute performance test was administered at the beginning and the close of each of the respective work and rest periods. During the two-hour period of continuous performance the feeling tone scale was marked by each subject without outside interference at equal intervals of twenty minutes. Briefly the experiment covering the four groups may be put as follows:

1. 10-minute mental test: two-hour rest: 10-minute mental test.
2. 10-minute mental test: two-hour mental work: 10-minute mental test.
3. 10-minute performance test: two-hour rest: 10-minute performance test.
4. 10-minute performance test: two-hour "slöjd" performance: 10 minute performance test.
5. Scoring of feeling tone scale at equal intervals of 20 minutes during the task period without outside interference.

In order to avoid the performance of two mental or two performance tasks at the same time in one group, it was planned to perform a pair of mental and performance tasks in one group and the remaining pair of task performances in the other group.

The results

The following are the scores for mental work and "slöjd" performance.

TABLE III

Control group

	Pre-test			After-test		
	Mult.	Div.	Total	Mult.	Div.	Total
Class I	7.00	4.46	11.46	6.86	6.40	13.26
„ II	5.13	3.26	8.39	5.66	4.86	10.52
„ III	5.50	2.12	7.62	5.81	3.87	9.68
„ IV	7.07	6.69	13.76	7.84	7.46	15.30
Total	6.13	4.01	10.15	6.49	5.55	12.05

TABLE IV

Experimental group

	Pre-test			After-test		
	Mult.	Div.	Total	Mult.	Div.	Total
Class I	5.00	2.13	7.13	4.00	1.00	5.00
„ II	6.07	1.07	7.14	4.84	0.69	5.53
„ III	5.75	4.00	9.75	4.75	3.16	7.91
„ IV	5.25	1.87	7.12	4.75	0.93	5.68
Total	5.48	2.21	7.69	4.57	1.37	5.94

Scores after matching the pre-test scores of the two groups

TABLE V

Control group

	Pre-test			N.	After-test		
	Mult.	Div.	Total		Mult.	Div.	Total
Class I	6.42	4.14	10.56	7	6.14	6.42	12.56
„ II	4.72	2.90	7.62	11	5.00	4.36	9.36
„ III	5.07	1.92	6.99	13	5.38	3.61	8.99
„ IV	6.60	5.20	11.80	5	7.00	6.20	13.20
Total	5.44	3.11	8.55	36	5.63	4.75	10.38

TABLE VI

Experimental group

	Pre-test			N.	After-test		
	Mult.	Div.	Total		Mult.	Div.	Total
Class I	5.25	2.33	7.58	12	4.00	0.91	4.91
„ II	6.50	1.75	8.25	8	5.00	1.00	6.00
„ III	6.11	4.22	10.33	9	4.66	3.55	8.21
„ IV	5.57	2.71	8.28	7	5.57	1.42	6.99
Total	5.80	2.75	8.55	36	4.69	1.69	6.38

TABLE VII

Significance of the differences between pre and after-tests

	N	M_1	M_2	S_1	S_2	r	t	P
Contr. group	36	8.55	10.38	3.37	3.46	0.64	3.80	< 0.001
Exper. group	36	8.55	6.38	3.37	3.33	0.92	9.00	< 0.001

TABLE VIII

Significance of the difference between the after-tests of the two groups

	N	M_2	r	t	P
Control group	36	10.38	0.67	6.70	< 0.001
Exper. group	36	6.38			

Experiments in "slöjd" performance. Scores after matching the pre-test scores of the two groups

TABLE IX

Control group

Judges	L			H			R			LHR		
	N	M_1	M_2	N	M_1	M_2	N	M_1	M_2	N	M_1	M_2
Class I	12	7.58	6.91	12	7.41	7.00	11	7.09	6.81	6	7.88	7.30
„ II	9	6.55	6.66	10	6.10	6.80	10	6.60	6.80	6	6.55	6.91
„ III	15	7.53	7.60	14	7.92	7.85	13	7.30	7.07	8	7.70	8.23
„ IV	8	8.50	8.62	8	8.75	8.62	7	7.42	7.85	9	8.70	9.03
Total	44	7.52	7.40	44	7.52	7.52	41	7.09	7.07	29	7.72	7.86

TABLE X

Experimental group

Judges	L			H			R			LHR		
	N	M_1	M_2	N	M_1	M_2	N	M_1	M_2	N	M_1	M_2
Class I	8	8.12	9.37	10	8.40	9.60	9	7.55	9.66	7	8.15	9.52
,, II	13	7.00	9.07	10	5.90	8.50	13	6.23	9.00	6	6.91	8.35
,, III	10	8.10	9.60	13	8.53	9.85	12	7.75	9.83	7	8.55	10.44
,, IV	13	7.53	9.15	11	7.18	9.27	7	6.56	9.00	9	7.26	9.11
Total	44	7.52	9.27	44	7.52	9.34	41	7.09	9.39	29	7.72	9.41

TABLE XI

Significance of the differences between pre and after-tests

Judges	Control Group			Experimental group		
	L	H	R	L	H	R
N	44	44	41	44	44	41
M_1	7.52	7.52	7.09	7.52	7.52	7.09
M_2	7.40	7.52	7.07	9.27	9.34	9.39
S_1	2.14	2.18	1.30	1.79	2.07	1.93
S_2	2.47	2.49	2.21	2.11	2.06	1.87
r	0.78	0.80	0.79	0.55	0.74	0.65
t	0.50	0.00	0.08	5.70	7.40	5.90
P				< 0.001	< 0.001	< 0.001

TABLE XII

Significance of the mean differences of the three judges between pre and after-tests

	N	M_1	M_2	S_1	S_2	r	t	P
Contr. group	29	7.72	7.86	1.85	2.05	0.66	0.46	
Exper. group	29	7.72	9.41	1.85	2.07	0.83	7.30	< 0.001

TABLE XIII

Significance of the difference between the after-tests of the two groups

	N	M_2	r	t	P
Contr. group	58	7.86	0.69	3.97	0.001
Exper. group	58	9.41			

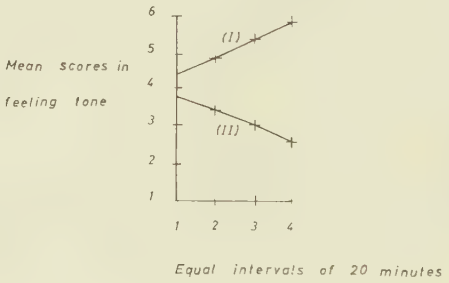
TABLE XIV

Correlations between judgments of scores of the three judges (on unmatched scores)

	L_1L_2	H_1H_2	R_1R_2	L_1H_1	L_2H_2	L_1R_1	L_2R_2	H_1R_1	H_2R_2
Control group	0.87	0.84	0.88	0.93	0.90	0.92	0.92	0.89	0.92
Exper. group	0.53	0.67	0.73	0.82	0.76	0.71	0.86	0.80	0.88

A.

Feeling tone in 4 equal intervals for "slöjd" performance (I) and continuous arithmetic work (II)



B.

PERFORMANCE-INTEREST DIAGRAM

Continuous arithmetic work

Interest \ Performance	+	0	−	
+				
0		2	20	22 { 15 were constantly bored throughout
−	3	2	29	34
	3	4	49	56

C.

Continuous "slöjd" performance

		Performance +	Performance 0	Performance −		
Interest	+	43	1		44	
	0	13	1		14	6 were constantly very satisfied throughout
	−					
		56	2		58	

As there were differences between the mental test in the control group (table III) and in the experimental group (table IV), it was necessary to match the two groups in their pre-test and then examine for significance differences. After matching the pre-test scores in the control group (table V) and the experimental group (table VI), we observe a significant difference between the pre-test and after-test of the two groups (table VII). As we controlled all possible and relevant factors during the experimental period, the differences of pre and after-test in the controlled and experiment groups (table VII) depend upon the influence of rest or work. Under these circumstances the significant difference in the after-tests of the two matched groups (table VIII) is due to the influence of the continuous two-hour arithmetic test. This difference is a fall in score at the end of a two-hour period of continuous arithmetic work.

In a similar manner the pre-test scores of the controlled (table IX) and experimental groups (table X) in "slöjd" performance were matched to see if there was any significant difference in the after-tests. The performance test scores, however, were judged by three judges independent of each other and they are well correlated (table XIV). No significant difference between pre- and after-performance tests was anticipated in the control group (table IX). But the experimental group indicates a significant difference (table XI), and in view of the fact that all possible and relevant factors were controlled during the period of con-

tinuous "slöjd" performance in the experimental group, the difference between the pre and after-tests depends upon the influence of continuous "slöjd" performance. This difference is an increase in the after-test of the experimental group (table XIII), and is influenced by the two-hour continuous "slöjd" performance.

Now the significant fall in the mental test at the end of the two-hour continuous arithmetic test and the significant rise in the performance test at the end of the two-hour continuous "slöjd" performance may be understood in relation to the interest changes of the subjects as reflected in their feeling tone ratings during the same period of the task performances. The respective feeling tone scores indicate a gradual but continuous fall in the subject's interest in continuous arithmetic work, while a gradual but continuous rise in interest in the "slöjd" performance during the two-hour period (table A). The differences in interest scores between the first and final intervals of the two-hour continuous task performances were correlated with the differences in scores between the pre and after-tests of the two continuous task performances. The data so obtained was tabulated in terms of positive (+), no change (0), and negative (—), in a performance-interest diagram (table B & C).

In continuous arithmetic work out of 56 pupils, 29 pupils show negative interest with fall in score, 20 no change in interest and fall in score, 2 no change in interest or in score, 2 negative interest and no change in score, and 3 negative interest but with rise in score. Out of the 22 pupils who show no change in interest, 15 are constantly bored throughout the experimental period and show regular fall in score. The interest variations reflected by the changes in feeling tone score of the individual pupils only indicate the rise or fall in performance output involved, not how great or small this rise or fall in score actually is. Except for the discrepencies of 7 pupils who show changing interest with the corresponding change in score, 49 pupils clearly indicate either diminished or unchanged interest with loss in score (table B).

Similarly in the two-hour continuous "slöjd" performance, out of 58 pupils, 43 show positive change in interest with rise in score, 13 no change in interest but rise in score, 1 no change in interest and no change in score and 1 positive interest but no change in score. Out of the 14 pupils who show no change, 6 are very

satisfied constantly throughout the performance period. Except for 2 pupils who show discrepencies in changes of interest and score, the diagram clearly indicates that 56 pupils out of the 58 show a positive rise in score with either increased or unchanged interest (table C).

The fall in score observed at the end of the two hours of continuous work due to the influence of continuous task processes (table VIII) corresponds overwhelmingly with the diminished interest of the pupils involved during the period of work (tables A, B). On the other hand the rise in score at the end of a two-hour period of "slöjd" performance due to the influence of the continuous performance (table XIII) corresponds overwhelmingly with the increased interest of the pupils involved in the continuous two-hour "slöjd" performance (tables A, C). The observed unrecorded conversation of the pupils during the continuous performance period lends support to the loss or gain in interest involved during the respective continuous two-hour period of arithmetic work and "slöjd" performance. But in order to understand more fully the nature of the two types of continuous task performance and their respective influence on output changes and interest, it was necessary to conduct new experiments.

Wood-work and mental tasks, differing in monotony

The experiments

The factors that would explain the effects of the continuous two-hour task performances—the decline and rise in output with the corresponding decline and rise in interest of the pupils in the two respective continuous tasks—may be monotony present in the continuous arithmetic test and the psychological variability present in the "slöjd" performance. Accordingly a continuous two-hour monotonous task performance like planing pieces of wood by jackplane was pitted against the continuous two-hour "slöjd" performance. Similarly a continuous two-hour complex mental task was pitted against the continuous two-hour arithmetic work. The complex lesson was planned so that "it should find natural points of correlation with important human activities and interests, and should extend into the whole

content of the school curriculum".[1] Young[2] describes such a lesson observed at a 'May-day' party where a complex lesson in arithmetic, art, social study, language etc., "grew out of need for a 'May basket' and a program for each guest".[3] On these lines a continuous two-hour complex lesson relating to physical environment (geography) and another relating to social environment (the morning hymn and the early life of Jesus Christ) were organized with the active help of the class teachers concerned.

The complex lesson relating to physical environment was centred on Västerås and the industrial districts which many pupils had either visited or had connections with. The topic involved social studies of labour and industrial conditions, elementary general science concerning metals like iron, copper, silver and gold, money economy and related arithmetical calculations, the history of Västerås church, religion, and the free-hand drawing of various styles of church.

The other lesson on social environment related directly to the morning hymn in the class room. Out of this grew a complex topic involving the early life of Jesus, bible reading, hymns and music, the geography of Arabia and Palestine, mapping the route to Palestine from Uppsala, general reference to the work of Dr. Hammarskjöld and the U. N. in Palestine, and lastly the way of life of the Bedouins with reference to their food, language, dress, animals etc.

A ten-minute performance test and a ten-minute arithmetic test were administered as before at the beginning and close of the two physical and two mental task performances respectively. Briefly stated the experiment conducted was as follows:

1. 10-minute performance test: monotonous two-hour performance of planing pieces of wood: 10-minute performance test.
2. 10-minute performance test: continuous two-hour "slöjd" performance: 10-minute performance test.
3. 10-minute arithmetic test: continuous two-hour calculations in multiplication and division: 10-minute arithmetic test.
4. 10-minute arithmetic test: continuous two-hour complex lesson: 10-minute arithmetic test.

[1] Report of the Dr. Zakir Husain committee p. 94, cf. During p. 95 ff.

[2] Young (1948) p. 3 ff., cf. During p. 65 f.

[3] Ibid. p. 3.

5. Scoring of the 7 degrees feeling tone scale at equal intervals of 20 minutes.

The new experiment would appear to be an extended repetition of the previous experiment with the addition of two similar but unlike task performances viz., a monotonous two-hour "slöjd" performance and a continuous two-hour complex lesson. Hence the exclusion of the control group in the new experimental situation would make no difference in proving the validity of our data.

The results

The scores are presented in the following tables (table XV–XXV).

TABLE XV

Monotonous "slöjd" performance

Judges	N	L		H		R		LHR	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Class I	12	9.08	6.00	9.58	6.41	9.58	5.83	9.43	6.07
„ II	14	6.78	3.85	7.78	4.78	7.35	3.71	7.30	4.11
„ III	13	7.69	4.76	7.84	5.23	7.84	4.46	7.81	4.80
„ IV	13	7.54	4.46	8.68	4.84	8.69	4.69	8.30	4.66
Total	52	7.73	4.73	8.44	5.28	8.33	4.63	8.17	4.88

TABLE XVI

Significance of the differences between pre- and after-tests

Judges	N	M_1	M_2	r	S_1	S_2	t	p
L	52	7.73	4.73	0.84	1.85	1.63	20.00	< 0.001
H	52	8.44	5.28	0.66	2.00	1.92	13.16	< 0.001
R	52	8.33	4.63	0.80	1.94	1.60	24.66	< 0.001
LHR	52	8.17	4.88	0.82	1.83	1.63	21.93	< 0.001

TABLE XVII

Correlation between judges

	L_1H_1	L_2H_2	L_1R_1	L_2R_2	H_1R_1	H_2R_2
r	0.87	0.83	0.91	1.00	0.97	0.77

TABLE XVIII

Varied "Slöjd" performance

Judges	N	L		H		R		LHR	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Class I	13	5.84	9.30	6.07	9.53	5.61	10.07	5.84	9.64
„ II	15	5.93	8.46	6.20	8.93	5.86	9.40	6.00	8.92
„ III	14	5.78	9.07	6.00	9.35	5.57	9.92	5.77	9.44
„ IV	15	4.66	9.80	4.93	10.06	4.46	10.66	4.67	10.17
Total	57	5.54	9.16	5.79	9.47	5.37	10.02	5.56	9.54

TABLE XIX

Significance of the differences between pre- and after-tests

Judges	N	M_1	M_2	r	S_1	S_2	t	P
L	57	5.54	9.16	0.42	1.88	1.82	15.08	< 0.001
H	57	5.79	9.47	0.36	1.93	1.84	13.62	< 0.001
R	57	5.37	10.02	0.34	1.91	1.78	16.03	< 0.001
LHR	57	5.56	9.54	0.37	1.87	1.76	14.21	< 0.001

TABLE XX

Correlation between the judges

	L_1H_1	L_2H_2	L_1R_1	L_2R_2	H_1R_1	H_2R_2
r	0.94	0.91	0.95	0.93	0.92	0.91

TABLE XXI

Continuous arithmetic work

	N	M_1	M_2
Class I	12	7.33	5.41
„ II	9	4.88	2.44
„ III	15	5.60	3.26
„ IV	24	6.37	4.62
Total	60	6.15	4.12

TABLE XXII

Significance of the difference between pre and after-tests

M_1	M_2	S_1	S_2	r	t	P
6.15	4.12	2.15	1.91	0.65	9.23	< 0.001

TABLE XXIII

Mean scores of output for continuous arithmetic work in four equal intervals

	N	I	II	III	IV
Class I	12	11.33	4.91	2.59	5.59
„ II	9	9.22	5.11	2.00	4.22
„ III	15	17.66	9.60	6.80	5.13
„ IV	24	5.66	2.79	2.00	1.58
Total	60	10.33	5.27	3.32	3.47

TABLE XXIV

Mental work (complex lesson)

	N	M_1	M_2
Class I	14	3.28	5.64
„ II	14	2.57	4.64
„ III	14	8.28	10.21
„ IV	14	8.35	11.00
Total	56	5.62	7.87

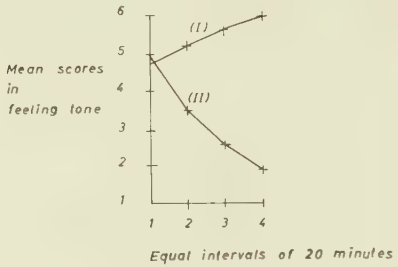
TABLE XXV

Significance of the above difference

M_1	M_2	S_1	S_2	r	t	P
5.62	7.87	3.43	4.05	0.88	9.37	< 0.001

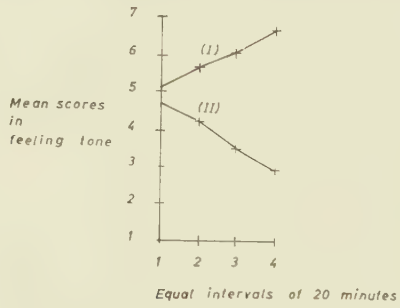
D.

Feeling tone for "Slöjd" performance (I) and for monotonous wood-work performance (II).



E.

Feeling tone for complex mental task (I) and for arithmetic work (II)



F.

PERFORMANCE-INTEREST DIAGRAM

"Slöjd"

		Performance +	Performance 0	Performance −	
Interest	+	34			34
	0	21			21
	−	2			2
		57			57

{ 8 very satisfied throughout

Monotonous wood work

Interest	Performance +	Performance 0	Performance −	
+				
0			1	1
−			51	51
			52	52

G.

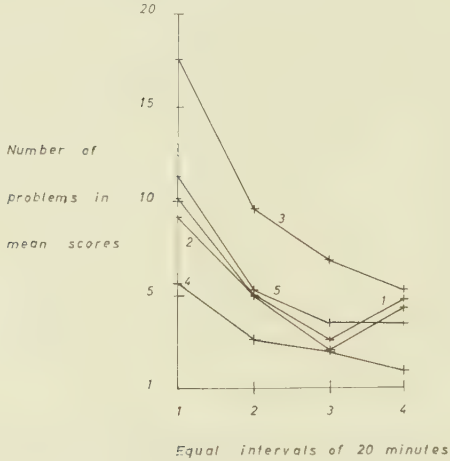
PERFORMANCE-INTEREST DIAGRAM

Complex mental task

Interest	Performance +	Performance 0	Performance −		
+	40	4	2	46	
0	5	1		6	5 constantly very satisfied
−	4			4	
	49	5	2	60	

Continuous arithmetic work

Interest	Performance +	Performance 0	Performance −		
+		1	2	3	
0	1	1	8	10	5 bored throughout
−	1	3	43	47	
	2	5	53	60	



The pre and after-test scores in monotonous "slöjd" performance (table XV) show significant differences (table XVI). The judgements of scores by the judges are significantly correlated (table XVII). Since all possible interfering variables were controlled during the period of performance this difference between the pre and after-test is due to the influence of the monotonous task performance. The significant mean difference 3.29 (table XVI) is the loss in score due to monotonous task processes of planing pieces of wood during the two-hour performance period.

Similarly in continuous arithmetic work the pre and after-tests (table XXI) show significant differences (table XXII). Since all possible interfering variables were controlled during the experimental period, the difference is due to the influence of the continuous arithmetic work during the two-hour work period. The significant difference 2.03 (table XXII) is the loss in score caused by the continuous two-hour arithmetic work processes.

Further, during the monotonous two-hour "slöjd" performance and the continuous two-hour arithmetic work, the interest of the pupils evidenced in their actual feeling states was recorded as before at four equal intervals of 20 minutes on a seven degree interest scale (D, E). The continuous decline in interest as evidenced by the continuous fall in the feeling tone throughout the two-hour monotonous "slöjd" and arithmetic work corresponds to the fall in score resulting from the respective two-hour task perform-

ances (tables XVI, XXI). In addition the differences in feeling tone scores at the beginning and close of the continuous two-hour task periods were correlated with the differences in the pre- and after-tests of the respective continuous tasks, and tabulated in terms of positive (+), no change (0), and negative (—) in a performance-interest diagram (tables F, G) as before. In monotonous "slöjd" performance 51 out of the 52 subjects indicate a negative interest with a negative performance score. Only one subject shows negative performance score with no change in interest. In continuous arithmetic work out of 60 pupils, 43 show more negative interest with loss in performance score, and 5 with loss are bored throughout the performance period. While the remaining 12 pupils show varying discrepencies in change of interest and performance score, only 2 pupils show positive performance score with negative or no change of interest. This indicates that losses in score in monotonous "slöjd" performance and continuous arithmetic work correspond overwhelmingly with the loss in feeling tone or interest of the subjects. This loss in score would appear to be due to deterioration either in quality or quantity of the involved repetitive task processes of performance. As far as the quantity of performance in the continuous two-hour arithmetic task is concerned, the number of arithmetical calculations correctly solved in every 20 minutes can be seen in table XXIII. There is a regular fall in the number of correctly solved problems (table H). In two of the groups there is a slight rise in performance output in the last interval in comparison with the previous one. That is due to the pupils' gradually avoiding the arithmetical calculations given and selecting instead comparatively easy ones as the task progressed during the two-hour work period. The groups in question in the final interval attempted of their own free will simple additions and subtractions which were comparatively satisfying, giving rise to a slight increase in performance output over the previous interval. But for this exception there is a regular fall in performance output in continuous arithmetic work corresponding to the regular fall in feeling tone score during the same period. It is thus reasonable to assume that the fall in score in the two-hour monotonous "slöjd" and arithmetic tasks is influenced by the declining interest or feeling tone during the same period.

On the other hand varied "slöjd" performance (table XVIII)

shows a significant positive difference between the pre and after-tests (table XIX) and there is close correlation between the judges in scoring (table XX). As all the interfering variables during the experimental period were controlled, this difference in score is influenced by the two-hour "slöjd" performance. The mean difference of 3.98 is the significant gain in the "slöjd" performance. Similarly the pre and after-tests in the complex lesson (table XXIV) show a significant difference influenced by the two-hour task of the complex lesson. The difference of 2.25 is a significant gain in the task performance (table XXV). The feeling tone score during the same period shows a gradual rise throughout the task performances of "slöjd" and the complex lesson (table D, E). Further the performance-interest diagram (table F) indicates that out of the 57 pupils engaged in the two-hour period of continuous "slöjd" performance, 34 pupils show increased interest with increased performance score, 8 pupils with gain maintain the highest interest throughout the performance period, and 13 with gain maintain a stable interest with increased performance score. Only two pupils show a negative interest with increased performance score. Out of the 56 pupils engaged in the complex mental task, 40 show increased interest with gain in score and 5 with gain maintain the highest interest with increased score. 4 subjects show no change in performance but increased interest, 1 no change in either interest or in performance, 2 show loss in performance but increased interest and 4 increase in performance but loss in interest (table G). Therefore except for the discrepencies in 6 subjects, an overwhelming number of 50 pupils show a positive or unchanged interest with increased or unchanged score.

The increased score with respect to "slöjd" performance and complex mental tasks appears to be a result of the psychological variability inherent in the continuous two-hour task processes as compared to the two-hour monotonous "slöjd" and arithmetic task processes.

Wood-work and mental tasks of differing monotony, continued for several days

The experiments

In order to study the stability of the results reported, it was desirable to make a closer investigation of the four types of

experimental task performance by repeating them for a period of one week (6 days).

Accordingly, the experiment in the four types of task performance reported above (p. 138) was conducted for six consecutive days with 136 fifth grade pupils from Uppsala Elementary schools. The experiment in continuous arithmetic work was conducted as before, while in monotonous "slöjd" (manual training) performance, pieces of wood measuring $35 \times 15 \times 2.5$ cm. were used for continuous planing. In conducting these two monotonous continuous performances for 6 consecutive days, it was assumed that the feeling-tone and output of performance of the following days would fall short of the score for the first day, due to increasing boredom.

The "slöjd" performance was conducted as before. A comparatively larger number of performance projects were selected from the class list, such as cups, small lamps, small tables, mandolins, boats, plates, wooden baskets etc., which would last the full two-hour experimental period during the whole week. For the complex mental task, three lessons were constructed around three different central themes, viz., 1 Festivals in general and Christmas in particular, 2. Winter sports, 3. A boat (which the boys had made just a few days before in the "slöjd" hall). The lessons were organized and planned in a 'concentrated' manner comprising all fields of knowledge suitable for such complex studies. The planned lessons and methods for putting them into operation were discussed in great detail with the class teachers concerned. The complex lesson for the first two days of the week was on festivals, for the next two days on winter sports, and the last two days were devoted to the lesson on the boat. These three complex lessons were assumed to differ in degree of interest. The complex lesson on the boat was assumed to be relatively highly motivated because of the spontaneous effort of the pupils involved in the task performance.

A ten-minute arithmetic test and a ten-minute "slöjd" performance test were administered at the beginning and close of the respective continuous experiments each day during the six days' work and performance. As before the 7 degrees rating scale in the interest or feeling tone of the subjects was scored at equal intervals of 20 minutes during the continuous performances for the whole week.

The results

The scores can be studied in the following tables (table XXVI–XXX).

TABLE XXVI

Monotonous "slöjd" performance, differences between pre and after-tests

a) 1st day:

Judges	L	H	R	LHR
N	30	30	30	30
M_1	8.57	8.93	8.50	8.67
M_2	4.73	4.77	5.37	4.95
S_1	3.76	2.88	2.59	2.59
S_2	1.82	1.77	1.71	1.60
t	6.00	8.32	7.45	10.33
p	< 0.001	< 0.001	< 0.001	< 0.001

b) 2nd day:

Judges	L	H	R	LHR
N	28	28	28	28
M_1	9.11	9.28	9.43	9.28
M_2	7.14	7.53	7.71	7.47
S_1	2.02	2.17	2.27	2.08
S_2	2.28	2.51	2.23	2.28
t	7.30	7.00	8.60	18.10
p	< 0.001	< 0.001	< 0.001	< 0.001

c) 3rd day:

Judges	L	H	R	LHR
N	30	30	30	30
M_1	10.30	10.17	10.17	10.21
M_2	8.23	7.70	8.13	8.02
S_1	1.95	2.11	1.75	1.86
S_2	2.14	2.25	2.09	2.07
t	5.91	5.10	6.80	6.44
p	< 0.001	< 0.001	< 0.001	< 0.001

d) 4th day:

Judges	L	H	R	LHR
N	32	32	32	32
M_1	9.12	8.97	9.25	9.22
M_2	6.53	6.41	7.31	7.21
S_1	1.92	2.05	1.89	1.90
S_2	2.42	2.23	1.93	2.10
t	7.19	6.56	6.69	5.74
p	< 0.001	< 0.001	< 0.001	< 0.001

e) 5th day:

Judges	L	H	R	LHR
N	31	31	31	31
M_1	9.68	9.42	9.77	9.63
M_2	7.13	7.16	7.22	7.16
S_1	2.26	2.68	2.52	2.42
S_2	2.46	2.77	2.46	2.41
t	9.44	7.79	9.44	8.52
p	< 0.001	< 0.001	< 0.001	< 0.001

f) 6th day:

Judges	L	H	R	LHR
N	31	31	31	31
M_1	9.03	9.22	9.39	9.21
M_2	7.39	7.61	7.74	7.58
S_1	2.36	2.12	2.36	2.09
S_2	2.23	2.35	2.28	2.22
t	6.56	4.60	6.11	6.52
p	< 0.001	< 0.001	< 0.001	< 0.001

TABLE XXVII

Varied "slöjd" performance, differences between pre and after-tests

a) 1st day:

Judges	L	H	R	LHR
N	30	30	30	30
M_1	5.47	5.77	5.87	5.70
M_2	7.83	8.20	8.00	8.02
S_1	2.32	2.43	2.42	2.33
S_2	2.12	2.24	2.19	2.35
t	6.55	7.77	7.89	6.63
p	< 0.001	< 0.001	< 0.001	< 0.001

b) 2nd day:

Judges	L	H	R	LHR
N	28	28	28	28
M_1	7.32	8.25	7.57	7.48
M_2	9.28	9.86	9.39	9.52
S_1	1.91	1.87	2.15	1.90
S_2	1.92	2.01	2.04	1.90
t	6.76	5.96	7.28	8.16
p	< 0.001	< 0.001	< 0.001	< 0.001

c) 3rd day:

Judges	L	H	R	LHR
N	30	30	30	30
M_1	7.83	7.80	8.00	7.21
M_2	9.70	9.87	9.83	9.81
S_1	2.16	2.29	2.16	2.13
S_2	2.16	2.03	2.00	2.00
t	7.48	6.90	9.15	11.30
p	< 0.001	< 0.001	< 0.001	< 0.001

d) 4th day:

Judges	L	H	R	LHR
N	30	30	30	30
M_1	7.63	8.00	8.40	8.01
M_2	9.60	10.00	9.97	9.86
S_1	2.59	2.68	2.64	2.61
S_2	2.01	1.91	1.97	1.89
t	6.20	6.01	6.10	6.17
p	< 0.001	< 0.001	< 0.001	< 0.001

e) 5th day:

Judges	L	H	R	LHR
N	27	27	27	27
M_1	7.48	7.85	8.11	7.81
M_2	9.92	10.37	10.26	10.18
S_1	2.77	2.63	2.23	2.50
S_2	1.86	1.65	1.72	1.76
t	6.42	6.63	5.37	7.90
p	< 0.001	< 0.001	< 0.001	< 0.001

f) 6th day:

Judges	L	H	R	LHR
N	27	27	27	27
M_1	7.52	7.89	7.29	7.58
M_2	10.07	10.37	10.52	10.17
S_1	1.91	1.91	2.05	1.90
S_2	1.99	1.88	1.75	1.69
t	18.21	8.27	12.92	9.59
p	< 0.001	< 0.001	< 0.001	< 0.001

TABLE XXVIII

Continuous arithmetic work, differences between pre and after-tests

	M_1	M_2	S_1	S_2	t	p
1st day	4.48	3.09	2.21	2.05	6.62	< 0.001
2nd day	5.28	3.87	2.68	3.01	4.70	< 0.001
3rd day	5.84	3.78	2.69	2.15	6.87	< 0.001
4th day	3.82	2.67	1.98	1.97	11.50	< 0.001
5th day	4.47	2.75	2.85	2.71	6.88	< 0.001
6th day	3.76	2.21	2.82	2.42	6.20	< 0.001

TABLE XXIX

Continuous arithmetic work, mean scores of output at four equal intervals

	N	I	II	III	IV
1st day	33	6.65	5.15	3.65	3.03
2nd day	32	4.93	5.08	4.29	3.26
3rd day	32	4.09	3.97	3.16	2.31
4th day	32	3.31	2.83	2.08	1.63
5th day	32	2.72	2.45	1.57	1.02
6th day	33	2.43	1.90	1.48	1.03

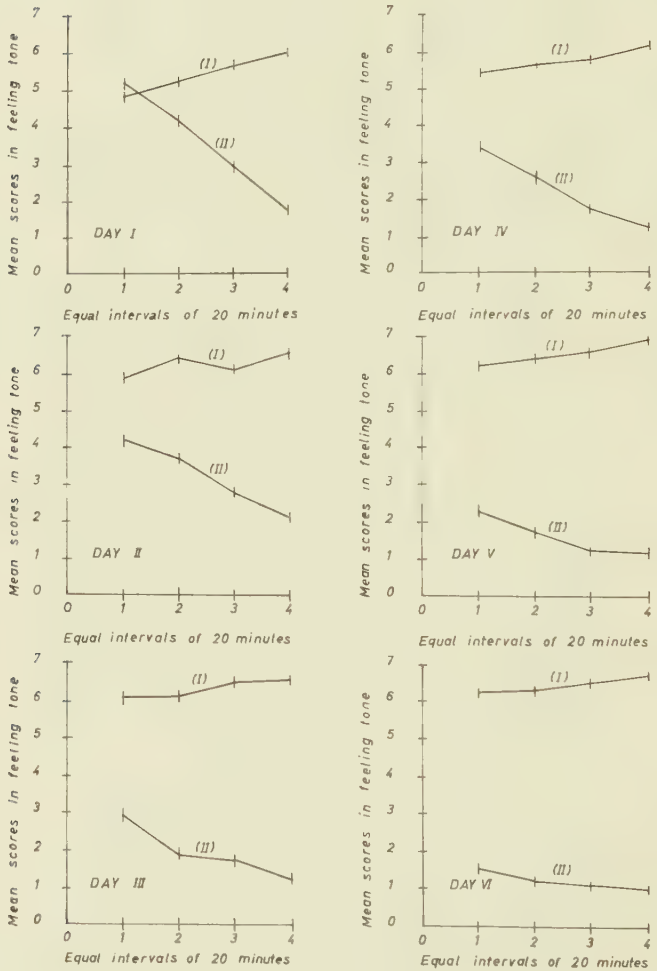
TABLE XXX

Complex mental task, differences between pre and after-tests

	M_1	M_2	S_1	S_2	t	p
1st day	5.13	6.06	2.06	2.54	3.10	< 0.001
2nd day	6.78	8.03	2.50	2.62	4.17	< 0.001
3rd day	7.59	8.87	3.15	3.13	4.27	< 0.001
4th day	7.23	8.68	3.25	3.07	4.39	< 0.001
5th day	6.00	8.67	3.25	3.41	7.42	< 0.001
6th day	5.67	8.03	3.39	3.93	6.55	< 0.001

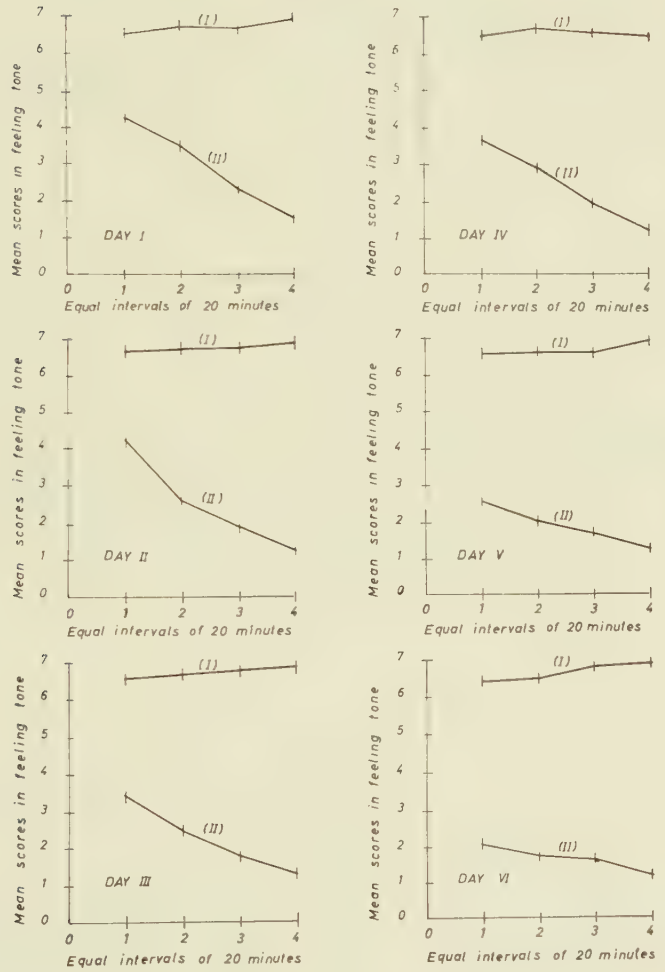
Feeling tone for complex mental task (I) and for arithmetic work (II)

Fig. J



Feeling tone for "slöjd" performance (I) and for monotonous wood-work (II)

Fig. K



PERFORMANCE-INTEREST DIAGRAM

TABLE L

Monotonous wood-work

1st day

Interest \ Performance	+	0	−		
+					
0			3	3	3 constantly very dissatisfied
−		1	26	27	
		1	29	30	

2nd day

Interest \ Performance	+	0	−		
+					
0			4	4	2 constantly very dissatisfied
−			24	24	
			28	28	

3rd day

Interest \ Performance	+	0	−		
+					
0			5	5	4 constantly very dissatisfied
−	1	5	19	25	
	1	5	24	30	

4th day

Interest \ Performance	+	0	−	
+			1	1
0			3	3 { 3 constantly very dissatisfied
−		3	25	28
		3	29	32

5th day

Interest \ Performance	+	0	−	
+				
0		1	18	19 { 18 constantly very dissatisfied
−			12	12
		1	30	31

6th day

Interest \ Performance	+	0	−	
+				
0	1	1	15	17 { 17 constantly very dissatisfied
−		4	10	14
	1	5	25	31

PERFORMANCE-INTEREST DIAGRAM

TABLE M

"Slöjd"

1st day

Interest \ Performance	+	0	−	
+	5	1		6
0	21	3		24 { 24 constantly very satisfied
−				
	26	4		30

2nd day

Interest \ Performance	+	0	−	
+	3			3
0	23	2		25 { 24 constantly very satisfied
−				
	26	2		28

3rd day

Interest \ Performance	+	0	−	
+	3	1		4
0	24	2		26 { 26 constantly very satisfied
−				
	27	3		30

4th day

Interest	Performance +	Performance 0	Performance −	
+				
0	25	3	2	30 { 28 constantly very satisfied
−				
	25	3	2	30

5th day

Interest	Performance +	Performance 0	Performance −	
+	5			5
0	21	1		22 { 22 constantly very satisfied
−				
	26	1		27

6th day

Interest	Performance +	Performance 0	Performance −	
+	5	1		6
0	21			21 { 21 constantly very satisfied
−				
	26	1		27

PERFORMANCE-INTEREST DIAGRAM

TABLE N

Continuous arithmetic work

1st day

Interest \ Performance	+	0	−		
+					
0			2	2	2 constantly very dissatisfied
−	2	5	24	31	
	2	5	26	33	

2nd day

Interest \ Performance	+	0	−		
+					
0		1	6	7	6 constantly very dissatisfied
−	4	4	17	25	
	4	5	23	32	

3rd day

Interest \ Performance	+	0	−		
+					
0			4	4	4 constantly very dissatisfied
−	2	1	25	28	
	2	1	29	32	

4th day

Interest \ Performance	+	0	−	
+				
0		1	2	3
−	1	1	27	29
	1	2	29	32

3 constantly very dissatisfied

5th day

Interest \ Performance	+	0	−	
+				
0	1		11	12
−		2	18	20
	1	2	29	32

11 constantly very dissatisfied

6th day

Interest \ Performance	+	0	−	
+				
0	2	2	14	18
−	1	1	13	15
	3	3	27	33

18 constantly very dissatisfied

PERFORMANCE-INTEREST DIAGRAM

TABLE O

Complex metal task

1st day

Interest \ Performance	+	0	−	
+	6	4	4	14
0	10	5	2	17 { 9 constantly very satisfied
−				
	16	9	6	31

2nd day

Interest \ Performance	+	0	−	
+	10		3	13
0	13	3	2	18 { 14 constantly very satisfied
−	1			1
	24	3	5	32

3rd day

Interest \ Performance	+	0	−	
+	4	2	2	8
0	15	3	3	21 { 18 constantly very satisfied
−	3			3
	22	5	5	32

4th day

Interest \ Performance	+	0	−	
+	6	4	3	13
0	10	2		12 { 12 constantly very satisfied
−	5		1	6
	21	6	4	31

5th day

Interest \ Performance	+	0	−	
+	9			9
0	20		1	21 { 20 constantly very satisfied
−				
	29		1	30

6th day

Interest \ Performance	+	0	−	
+	9	3		12
0	15	2	1	18 { 18 constantly very satisfied
−	1			1
	25	5	1	31

TABLE XXXI

Consolidated table for the four types of continuous work conducted during the week

A. *Monotonous slöjd performance*

				Mean output at four equal intervals		*Interest*	
Day	N	M_1	M_2	M_1	M_4	M_1	M_4
1	30	8.67	4.95			4.07	1.53
2	28	9.28	7.47			4.18	1.25
3	30	10.21	8.02			3.33	1.30
4	32	8.75	6.26			3.56	1.28
5	31	9.63	7.16			2.52	1.32
6	31	9.21	7.58			1.94	1.19

rho = 0.65

B. *Varied slöjd performance*

				Mean output at four equal intervals		*Interest*	
Day	N	M_1	M_2	M_1	M_4	M_1	M_4
1	30	5.70	8.02			6.53	6.87
2	28	7.48	9.52			6.68	6.82
3	30	7.21	9.81			6.50	6.83
4	30	8.01	9.86			6.47	6.47
5	27	7.81	10.18			6.52	6.93
6	27	7.58	10.17			6.44	6.85

rho = 0.51

C. *Continuous arithmetic work*

				Mean output at four equal intervals		*Interest*	
Day	N	M_1	M_2	M_1	M_4	M_1	M_4
1	33	4.48	3.09	6.65	3.03	5.19	1.69
2	32	5.28	3.87	4.93	3.26	4.22	2.06
3	32	5.84	3.78	4.09	2.31	2.94	1.16
4	33	3.82	2.67	3.31	1.63	3.34	1.22
5	32	4.47	2.75	2.72	1.02	2.22	1.09
6	33	3.76	2.21	2.43	1.03	1.52	1.00

rho = 0.83

rho = 0.94

D. *Complex mental task*

Day	N	M_1	M_2	*Mean output at four equal intervals* M_1	M_4	*Interest* M_1	M_4
1	31	5.13	6.06			4.94	5.90
2	32	6.78	8.03			5.94	6.50
3	32	7.59	8.87			6.09	6.50
4	31	7.23	8.68			5.39	6.10
5	30	6.00	8.67			6.23	6.77
6	31	5.67	8.03			6.23	6.74

rho = 0.58

N. B. Rho values are between mean performance M_1–M_2 and mean interest M_1–M_4. For rho 0.94 in table XXXI C, see the text.

Table XXVI, a–f, presents the scores for the monotonous "slöjd" performance during the week. The fall in score each day during the week is significant. The correlation between the judges indicates close correspondence in the judgement of scores for each day's performance (r = about 0.90).

The scores for "slöjd" performance are presented in table XXVII, a–f. There is a significant gain in the scores of the after-tests during the week. There is also agreement in the judgement of scores by the judges during the week (most of correlation coeffecients 0.90).

Continuous arithmetic work during the week shows losses in the scores of the after-tests (table XXVIII). These losses in scores during the week are significant. Mean scores of output taken at four equal intervals during the two hours' work decrease (table XXIX). The after-tests in connection with complex mental tasks during the week indicate a significant gain in scores (table XXX).

As reported above (p. 130) the interest of the pupils in work and performance during the week as expressed in their actual feeling states is graphically shown (fig. J and K). In the monotonous tasks the feeling-tones decrease during the two-hour working period as well as successively from day to day during the week.

In addition the difference in feeling-tone scores between the beginning and the end of the two-hour period of work during the week corresponds with the difference in the scores of the pre

and after-tests of the respective tasks for the same period (tables L, M, N, O).

In monotonous wood-work performance 29, 28, 24, 28, 30 and 25 pupils respectively show decreased performance scores with decreasing or unchanged feeling-tone during the successive days of the week (table L). Further, the total number of wood pieces planed decreased progressively during the week.

In "slöjd" performance 26, 26, 27, 25, 26 and 26 pupils respectively show increased performance scores with increased or unchanged feeling-tone during the week (table M).

In continuous arithmetic work 26, 23, 29, 29, 29 and 27 pupils respectively show a fall in score along with decreased or unchanged feeling-tone during the week (table N). During the same period of arithmetic work, the speed of performance, as indicated by the number of problems solved, progressively decreases during the two-hour period (table XXX). At the same time the output of problems solved during the first interval on the second and following days of the week does not reach the level of output of the first interval on the first day.

In the complex mental task, 16, 23, 19, 16, 29 and 24 pupils respectively show increased scores with increased or unchanged feeling-tone during the week (table O).

Thus far the results of the six-day experiment in the four groups of the two-hour "slöjd" performances and mental tasks confirm the previous results. However, there are other features of the six-day experiment that remain to be explained. A consolidated table containing a summary of the experimental results from all the groups is interesting in this connection (table XXXI).

Interpretation and discussion

For an adequate explanation of the results and interpretation of the scores of the experiment during the 6 consecutive days (table XXXI), it is necessary to remember two important conditions which govern the whole range of the experiment. 1. The tests before and after the continuous two-hour work period are repeated from day to day, in "slöjd" in exactly the same form, and in arithmetic in the form of similar problems. Consequently a training effect on the performance in these tests during the following days of the week may be expected. 2. The interest rating is

necessarily made in connection with the work or task performance period, and not in relation to the tests administered before and after the two-hour period of work or performance. The interest ratings therefore, might possibly be transferred to the tests to the extent that there is any existing similarity between the test and the experimental task.

Bearing in mind these conditions, table XXXI can be explained as follows.

In A an evident training effect can be noted in the test results for the first three days, and the pupils have probably found the performance test to be more interesting than the performance task itself. Thus the discrepencies found between the results of the test performance and those of the interest ratings are easy to understand. But the differences in both variables for every single day go hand in hand, and as we have seen, there is also an evident correlation between the different pupils' decreasing test results and diminishing interest. Yet the correlation (ϱ) between mean output (beginning and end) during the six days and the mean interest ratings (beginning and end) is + 0.65, which proves that the motivational factors partly explain the variations in the mean test scores.

In B, we observe a training effect for at least the first four days. The performance test and the performance task are rather similar. Therefore the interest ratings during the task performance are probably valid for the performance test also. Further, the interest rating from the very beginning of the task performance is already extremely high, and what is more, during the task performance it shoots up almost to the top rating of seven. In spite of the training effect the correlation between the mean test results and the interest ratings is + 0.51. The increase in mean test results and the mean interest ratings go hand in hand for every single day with only one exception. As shown above the individual differences in both variables are evidently correlated.

In C, the training effect also appears for the test results during the first three days. On the other hand, the test and the two-hour work period are very similar. Therefore, the test as well as the task may have almost the same motivational value for the pupils. This explains the high correlation + 0.83 between the mean test results and the mean interest ratings. As in A and B the mean

differences for every single day go hand in hand without exception. The individual differences in the two variables are, as we have seen, very closely connected. The correlation between the mean output differences and the mean differences in interest ratings during the week is about the same, + 0.94. This means that the variations in the mean interest changes explain almost all of the variations in the mean output changes.

The test results in D also indicate a training effect as in A, B and C. The tests were presumably not as interesting as the tasks themselves. However, we must take into consideration another important factor. The 'mental' tasks during the working period were varied during the week. The first four days were given to complex lessons on 'festivals' and 'winter sports', while the last two days were devoted to the complex lesson on 'the boat'. In the course of the complex lessons during the first four days, although an attempt was made "to make the pupil an active and independent worker in the process of the acquisition of information"[4] with the indirect guiding influence of the teacher, a direct participation by the pupils in the learning processes appeared less evident. Several factors seem to explain this discrepency. A spontaneous situation which could give the pupils a genuine emotional experience and so stimulate them to a maximum amount of activity seemed, for instance, to be absent. At the same time the teacher was comparatively more occupied with the teaching material than with "its interaction with the pupils present needs and capacities".[5]

In the complex lesson on 'the boat', on the other hand, the pupils had spontaneously participated in a creative and purposeful task a few days before. The "slöjd" hall itself was the centre of instruction, and here the materials and tools used before were ready at hand for discussion. There were thus comparatively greater possibilities for the direct participation of the pupils in the course of instruction. The spirit of experimentation pervading the task processes, which were at the same time entertaining, gave the pupils real emotional experience that stimulated them to give their best during the performance period. The subject-matter, comprising new facts and relations involved in the independent investiga-

[4] Pinkevitch p. 238.

[5] Dewey (1935) p. 215.

tion of the task processes, was of genuine interest to the pupils, constantly motivating them to give increased attention to the task processes.

These considerations would mean that the motivational value of the three complex mental tasks as such is probably not the same.[6] The consequences of the two last-mentioned factors upon the work are that the interest ratings may slip from day to day because of the task differences, and further, their validity for the test problems cannot be as good, for instance, as in C. In spite of all these considerations the correlation between mean test results and mean interest ratings is + 0.58. As evident in A, B and C the differences for every single day go hand in hand without any exception. The individual differences in the two variables, as stated before, show for the most part a good covariation.

Under these circumstances the simplest and most straightforward conclusion seems to be that all the figures are influenced by motivational changes in connection with and during the tests and the tasks.

Now the mean output series (table XXXI C) indicates that every day the output during the work period diminishes and that at the beginning of the next day some recovery can be observed, but not to the extent of the resulting output at the same period of the previous day. This seems to agree with Hull's[7] theoretical constructs of reactive inhibition (I_r) and conditioned inhibition (${}_sI_r$). Now if the output decrement evident in continuous arithmetic work during the six consecutive days may be interpreted in terms of the reported "reactive inhibition" and "conditioned inhibition", "reactive inhibition" as a motivational state is supposed to dissipate "with the passage of time".[8] Consequently the interest rating at the beginning of the second day ought to be as high as at the beginning of the first day and so on for the following consecutive days. But this is not the case. Instead the figures decrease from day to day. The output decrement may then perhaps be considered

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[6] Browne (1953) in an interesting experiment in which he presented his subjects with tasks involving different degrees of effort demonstrated "that there was an inverse relationship between deterioration caused by so called fatigue and the mental effort demanded by the task" (p. 140).

[7] Hull (1943) p. 282 f., (1951) p. 75 f., (1952) p. 10.

[8] Hull (1951) p. 74.

to be in some degree permanent due to "conditioned inhibition". Apart from all the objections to this construct and its experimental evidence[9] this output decrement *considered as a consequence of a habit,* may not, according to the theory itself, be reflected in a rating procedure such as the one presented in table XXXI. The reduction in output during a single day may perhaps depend to some extent upon "reactive inhibition" and that from day to day perhaps upon "conditioned inhibition". But this does not seem to be the only explanation as the rating figures reveal a different story.

The continuous arithmetic task processes involving continual repetition of the same response tends to create a situation which becomes increasingly "intolerable".[1] The corresponding progressive fall in feeling tone scores during the consecutive days, along with the unrecorded conversation of the pupils giving psychological expression to their feelings of discomfort, strain and dissatisfaction, reinforces the view that the monotonous task process is the basis for a decrease of the original drive state.

The organism's "process of motivation according to the model 'need-drive-action-recovered balance' "[2] needs therefore a readjustment. The interest ratings associated with the continuous task processes are considered to be cognitive anticipations of the different known actions and their consequences for the subjects in connection with their actual motivational states.

With the above discussion in mind we may readily understand the figures in table XXXI C. During the monotonous task of the first day the pupils get satiated, if not over-satiated, and their experience may perhaps therefore be characterized as negative. This is reflected in the low interest rating at the end of this day. The following day the pupils will immediately anticipate their previous day's experience as a consequence of their work. This is reflected in the interest rating being lower at the beginning of the

[9] Ellis (1953) p. 384. Pavlov (1928) found that in the acquisition of the conditioned salivary responses the number of drops secreted on each trial gradually decreased if the number of trials in a session was greatly increased, but on the following day the first few trials showed complete recovery (p. 81 ff.).

[1] Lewin (1938) p. 284.

[2] Sjöstrand (1958) p. 238.

following day than at the same time on the first day. Under these circumstances they will not work as hard as before and consequently the output diminishes. The more often the negative experience of monotonous work is repeated, the stronger will be the tendency for the growth of this anticipation from day to day. Accordingly the changes in original need and drive states during the experiment as a whole, the probable dissatisfaction in connection with the work, and the conception of 'interest' as an anticipatory mechanism which regulates all the 'drive currents', can explain the results for the most part. It is to be remembered that the correlation + 0.94 does not give much scope for the play of other mechanisms, if the decrease in interest rating is understood mainly as a consequence of diminishing motivation during the week, and if output is influenced by the regulatory mechanism mentioned.

Conclusion

In view of these considerations the reported output changes during a two-hour period of continuous task performance are to be put in relation to the drifts in motivation. The rise and fall in output is dependent on the nature of the task processes—the monotonous continuity and the psychological variability involved in the two-hour period of continuous task performance. Accordingly a two-hour task performance in which the task processes are characterized by psychological variability and qualified by emotional pleasantness, tends to maintain the directedness and continuity of the performance processes during the two-hour period.

A continuous two-hour performance of integrated Basic manual and intellectual activity would appear therefore to be in line with the nature of such task processes. The Basic manual and intellectual activity that forms the integral part of the "Basic Education" programme certainly involves variation with all its implications for motivation of behaviour. Therefore the inclusion of a two hour period of continuous integrated activity of the nature described in the educational programme need have no objection. From the physiological point of view there are, as it seems, no risks and the motivational conditions, which are most important, are fully guaranteed.

ZUSAMMENFASSUNG

Das Problem

Im „Grundunterricht" (Basic Education), dem anerkannten nationalen pädagogischen Leitziel der Indischen Demokratischen Republik für die Schüler von 6 bis 14 Jahren, bildet eine Form integrierter manueller Betätigung den Kern der allseitigen Entwicklung der Fähigkeiten des Individuums, während die Schulbildung als Ganzes auf einen integrierten Lehrplan ausgerichtet ist, der seinen Mittelpunkt in der „Elementaren manuellen Betätigung" hat. Eine zweistündige Unterrichtsperiode für die Ausführung solcher Aufgaben kann jedoch Müdigkeit hervorrufen und folglich die verschiedenen geistigen Tätigkeiten ungünstig beeinflussen. Diese Dissertation ist ein Versuch, dies Problem zu ergründen.

Der Begriff der Ermüdung

Obwohl die Ermüdung allgemein als Realität anerkannt wird, ist ihr Wesen doch ziemlich undeutlich, da der Begriff so verwendet wird, daß er einen weiten Umkreis von Phänomenen umfaßt und einen komplizierten Wirkungszusammenhang physiologischer und psychologischer Faktoren während des Zeitraumes, in dem die Aufgaben ausgeführt werden.

Die physiologischen Veränderungen, die organische Funktionen auslösen, welche einen Teil des Begriffs der Ermüdung ausmachen, sind Gegenstand ausgiebiger experimenteller Untersuchungen gewesen. Die Ergebnisse haben keinen festen Zusammenhang zwischen den physiologischen Prozessen und der Effektivität der Arbeit gezeigt. Zudem haben physiologische Messungen an Blut, Urin, Schweiß usw. keinerlei charakteristische Veränderungen nachweisen können, obwohl das Individuum sich müde fühlte. Eine Prüfung der zahlreichen Studien, die sich mit

den verschiedenen Beschwerden organischer Ermüdungserscheinungen beschäftigen, läßt den Begriff selbst unklar und undeutlich.

Ermüdung in Termini für Gefühlslagen auszudrücken, würde zu endlosen Auslassungen führen, die nicht experimentell nachprüfbar sind. Subjektive Empfindungen von Müdigkeit können z. B. leicht mit solchen der Depression und emotionalen Reaktionen vermischt werden, die im allgemeinen mit psychoneurotischen Symptomen verbunden sind.

Eine Durchsicht der überaus umfangreichen Literatur zur Erforschung der Ermüdung ergibt keine befriedigende und scharfe Definition des Begriffs. Als ein Ausweg aus dieser Schwierigkeit erscheint der Versuch einer Begriffsbestimmung in Bezug auf eine bestimmte Arbeitssituation. Unter normalen Arbeitsbedingungen können sich Veränderungen in der kontinuierlichen Tätigkeit in Form von Leistungsrückgängen, sei es quantitativ oder qualitativ oder beides, darstellen. Gemäß diesen Überlegungen liefern Schwankungen in den Leistungen, die sich bei fortlaufender Arbeit unter normalen Bedingungen ergeben, eine Definition von Ermüdung für diesen Bereich. Alle in den physiologischen und psychologischen Prozessen wirksamen möglichen Faktoren wären dann zu erforschen, um eine genauere Vorstellung der Gründe dieser Veränderungen zu vermitteln.

Nun können die Leistungsveränderungen während einer Periode der kontinuierlichen Tätigkeit an Aufgaben unter normalen Arbeitsbedingungen sowohl bei körperlicher wie bei geistiger Tätigkeit auftreten. Anerkanntermaßen können körperliche und geistige Betätigung in der gesamten Aktivität des Organismus nicht getrennt werden, da jede ein wesentlicher und integrierender Bestandteil der andern ist. Es wäre jedoch prinzipiell möglich, die spezifischen bei der betreffenden Tätigkeit mitspielenden Faktoren zu sondern. Die Arbeitsergebnisse können bald unmittelbar und zum größeren Anteil auf Muskelprozesse, bald auf Nervenprozesse im Gehirn zurückgehen. Zum Zweck der Beschreibung dürfte es daher vorteilhaft sein, von körperlicher (muskulärer) und geistiger (mentaler) „Ermüdung" bzw. Leistungsveränderungen zu reden.

Muskuläre Leistungsveränderungen

Die mit Muskeltätigkeit verbundene Arbeitsleistung kann nicht durch Messung der körperlichen Wärmeentwicklung hinlänglich wiedergegeben werden. Der Verbrauch an energiespendenden Substanzen, die Ansammlung von Milchsäure und die Bildung von Kohlendioxyd sind zugehörige Arbeitsintensitäten, die die kontinuierlichen Prozesse der Ausführung von Aufgaben mit sich bringen. Mit beträchtlicher experimenteller Beweiskraft läßt sich zeigen, daß bei mäßigen Arbeitsbelastungen weder überschüssige Milchsäure noch Kohlendioxyd im Blut erscheinen. Der übermäßige Aufwand an Energie bei mäßiger Anstrengung ist ebenfalls gering. Unter den homöostatischen Bedingungen eines Zustandes der Beständigkeit („steady state") können mäßig schwere Aufgaben ohne bemerkenswerte Einbuße an Produktivität ausgeführt werden.

Jedoch ist es natürlich günstig für die Erledigung einer Aufgabe, wenn sie variiert werden kann, so daß durch die sich ergebenden Gelegenheiten zur Abwechselung zwischen Ruhe und Aktivität die Arbeitslast auf verschiedene Muskeln verteilt wird, wodurch sich diese auf einer höheren Stufe der Ausgewogenheit erholen können. Kontinuierliche Ausführung von Aufgaben bringt unter diesen Umständen die Tendenz hervor, die Produktivität auf einem optimalen Niveau zu halten. Darüberhinaus bietet die kontinuierliche Arbeit an verschiedenen Aufgaben gute Möglichkeiten für die Entwicklung und Stärkung der betreffenden Muskeln, indem sie zu ihrem eigenen Besten sich betätigen dürfen. Unter diesen Umständen zeigen die ausgelösten physiologischen Mechanismen als Auswirkungen gesteigerte Bereitschaft zu vergleichsweise größerem Sauerstoffverbrauch und stärkerer Blutzirkulation in den belasteten Muskeln. So werden Stärke, Kraft und Ausdauer der Muskeln vergrößert, was wiederum die Leistungskraft steigert und erhöhte Produktivität bewirkt.

Geistige Leistungsveränderungen

Funktionale Veränderungen in Neuren sind mit dem Sauerstoffverbrauch und Energieaustausch während der Stoffwechselprozesse geistiger Anstrengungen verbunden. Der Oxydationsprozeß bewirkt die Bildung von Milchsäure und Kohlendioxyd,

und es wird Wärme freigesetzt. Es wurde gezeigt, daß der Wärmeüberschuß zufolge geistiger Aktivität nicht groß ist. Wenn andererseits der Nerv während der Prozesse der Tätigkeit sehr häufig gereizt wird, ist die durch die Impulse freigesetzte Wärme noch geringer. Es läßt sich experimentell mit außerordentlicher Sicherheit nachweisen, daß Nerventätigkeit mit dem Sauerstoff stattfinden kann, der bei in Ruhezustand vorhandenem Metabolismus verfügbar ist, und daß zusätzliche Sauerstoffaufnahme durch aktive Nervenzellen während geistiger Arbeitsprozesse ganz unnötig ist. Ausgiebige experimentelle Bestimmungen von vermehrtem Sauerstoffverbrauch, dem besten Indikator für Energieumwandlung während anhaltender und intensiver geistiger Anstrengungen, liefern dafür einen Wert von 3 bis 4 %. Diese geringe Zunahme wird den außer-nervlichen Elementen wie der Muskeltätigkeit oder der Unruhe zugeschrieben, die das Subjekt bei längerer geistiger Anstrengung fühlt. Vielleicht können die biochemischen Veränderungen, die die Prozesse geistiger Aktivität begleiten, in der Struktur der zerebralen Aktivität wiederum verteilt werden. Vermehrte funktionale und metabolische Tätigkeit kann ihr Gegengewicht in Zonen verringerter Aktivität haben, so daß der gesamte zerebrale Sauerstoffverbrauch unverändert bleibt. Es soll jedoch nicht bestritten werden, daß das Gehirn gegen Sauerstoffmangel sehr empfindlich ist. Eine starke Diskrepanz zur zerebralen Stoffwechseltätigkeit kann organische Veränderungen in Beziehung auf den Sauerstoffverbrauch hervorrufen. Aber derartige Möglichkeiten können bei maßvoller geistiger Tätigkeit ohne Gefahr außer Betracht gelassen werden. Der zerebrale Bedarf an Sauerstoff zur Aufrechterhaltung des Metabolismus in funktionaler Ruhelage scheint für durchschnittliche geistige Aktivität auszureichen, ohne daß eine besondere Aufnahme an Sauerstoff dafür erforderlich wäre. Die Bildung von Milchsäure und Kohlendioxyd während der Prozesse geistiger Tätigkeit kann auch primär im Zusammenhang mit dem in Ruhelage vorhandenen Metabolismus erklärt werden. Eine gewisse Konzentration von Milchsäure und Kohlendioxyd, die für den Stoffwechsel im Ruhezustand gebraucht wird, ist in dem ruhenden Nerv immer vorhanden. Versuchsergebnisse liefern keinen Nachweis für überschüssige Milchsäure und Kohlendioxyd im Gehirn während geistiger Anstrengungen. Der leicht erhöhte Prozentsatz

von Milchsäure im Gehirn, der bei einigen experimentellen Untersuchungen beobachtet wurde, ist der emotionalen Erregung zuzuschreiben, welche mit glykolytischen Prozessen während der Aktivität verbunden und vorübergehender Natur ist. Unter diesen Umständen kann die geistige Leistung unbeeinflußt bleiben von Nervenprozessen, die durch die Stoffwechselprozesse geistiger Anstrengung bedingt sind.

Es sind Versuche unternommen worden, die Auswirkungen fortgesetzter geistiger Arbeit auf die geistige Leistungskraft in arithmetischen Rechenaufgaben, Gedächtnis-Tests usw. zu bestimmen. Der größere Teil dieser Studien weist leichte Variationen in den Leistungen aus, aber die geistige Leistungsfähigkeit an sich war gewöhnlich auch bei längerer Arbeit nicht geringer.

Die Wechselwirkung zwischen Muskel- und Nervenelementen

Leistungsveränderungen können auf die Verbindungselemente in der neuromuskulären Synapsis zurückgeführt werden. In diesem Falle kann der feststellbare Leistungsabfall in einem gewissen Ausmaß einem Versagen der verbindenden Synapsen bei der Reizvermittlung zuzuschreiben sein. Afferente Impulse von den peripherischen Prozessen her veranlassen gleichfalls die zentralen Synapsen, den „Ermüdungs"-Reiz zu erzeugen, und hindern so den Organismus daran, sich zu schädigen. Diese Rückkopplung reduziert die ursprüngliche Intensität der Reaktion während fortgesetzter Reizung. Die Schwächung der Impulse, die auf neurale Unerregbarkeit zurückgeht, ist darüberhinaus ein Geschehnis von charakteristischer Bedeutsamkeit und kann nicht bloß durch Bezeichnung als Verlangsamung der Reizvermittlung forterklärt werden. Es scheint eine Gipfelphase der Unerregbarkeit zu geben. Tatsächlich findet sich auch einiger experimenteller Beweis für die Existenz von korrespondierenden Lücken oder Unterbrechungen während des Ablaufs der Prozesse bei der Aufgabenausführung, die als „Blockaden" bezeichnet werden. Verschiedene Studien aus der Massenpraxis berichten von dem häufigen Auftauchen solcher „Blockaden" während dieser Aufgaben-Prozesse, die einen Leistungsabfall hervorrufen. Die refraktäre Phase ist daher in Verbindung zu setzen mit einer Hemmung in den zentralen Synapsen. Aber die auf solches Versagen zurückzuführende Abnahme in der Reaktion auf Reize ist nicht so zu verstehen, als ob

der Mechanismus völlig außer Funktion gesetzt sei. Während wiederholter Arbeitsprozesse an Aufgaben paßt sich der neuromuskuläre Mechanismus vielmehr rasch den neuen Bedingungen an und gewinnt einen Zustand der Ausgeglichenheit auf der Basis einer reduzierten Funktion.

Die obgenannten hemmenden Prozesse scheinen jedoch keine wichtige Rolle bei dem Leistungsschwund zu spielen, der bei fortgesetzter mäßig anstrengender Aufgabenerledigung auftritt. Der wirkliche Grund für Abnahme der Arbeitsleistung dürfte daher woanders zu suchen sein.

Antriebsbedingte Prozesse

Der Leistungsabfall kann zurückgehen auf eine Reaktionshemmung als „negativen Antrieb". Die Bedingungen, die die Leistungsveränderungen bestimmen, sind in anderer Hinsicht natürlich mit den primären und sekundären Antrieben in Verbindung zu setzen und mit dem daraus folgenden Zustand von Konzentration auf die Aufgabe, der alle für den Beginn, die Aufrechterhaltung und die Zielgerichtetheit der Anstrengung notwendigen psychologischen Prozesse auslöst. Experimentelle Ergebnisse bei der „Aufheizung" von Leistungskurven stützen die Auffassung, daß der Erfolg die ursprünglichen Antriebe und Anreize steigert und so die Leistung erhöht. Während kontinuierlicher Aufgabenerledigung kommt es zu Zerstreutheit und Ablenkung der Aufmerksamkeit wegen der mitverursachten Prozesse von Rivalität und Konkurrenz zwischen Reaktionen, die Priorität voreinander fordern: Sie äußert sich in geschwächter Reaktion und im Eintreten von Blockaden. Der in den einander konkurrierenden Tendenzen auftretende Konflikt geht oft mit dem Gefühl der Langeweile überein. Diese Langeweile beruht auf der gleichförmigen und kontinuierlichen Natur der Arbeitsprozesse, die ein verringertes Maß von Antrieb und damit Unlust und den Wunsch, die Arbeit abzubrechen, hervorruft. Das Subjekt muß daher auf andere anregende und angenehme Verhaltsweisen verzichten zugunsten forcierter Fortsetzung der vorliegenden Aufgabe. Konzentration und Anstrengung erhöhen sich, wenn sich der Geist zu vergleichsweise interessanteren Erinnerungen und Gegenständen hingezogen fühlt. So schaffen die Befriedigung (zunächst) natürlicher Neigungen und Wünsche und die wiederholte Unterdrückung aller anderen

Wünsche und Tendenzen Druck und Spannung während der Erledigung der Aufgabe. Diese „unerträgliche" Situation ruft Gefühle von „Ermüdung" hervor oder Einbuße an Befriedigung, die die objektive Leistung beeinflussen. Dieser Rückgang der Leistung kann seinerseits teilweise einen erhöhten Verlust an Befriedigung bewirken.

Monotonie ist nach allgemeiner Ansicht mit dem Zustand der Gelangweiltheit verbunden. Vielleicht sollten wir auf die Scheidung zwischen Monotonie und Langeweile kein Gewicht legen, da das Subjekt selbst die Situation als sowohl langweilig wie eintönig beschreiben würde. Eintönigkeit mit ihren Charakteristika der wiederholten und abwechslungslos sich hinziehenden Aufgabenerledigung und beschränkten Gelegenheiten für sensorische Variation ist auch ein Problem der Stärke des Antriebs. Die verringerte Antriebsstärke bei Monotonie und Langeweile resultiert in einen akkumulativen Prozess, wobei sie geringere Aktivierung erzeugt mit folgender Schwächung der sensorischen Aufnahme usw.

Unmittelbar erheblich für Langeweile und Eintönigkeit bei gemindertem Antrieb ist das Prinzip der Variabilität des Verhaltens. Hierher scheint die Tatsache zu gehören, daß die Variabilität von den sich dazu ergebenden Gelegenheiten für untersuchendes, unterscheidendes und handhabendes Verhalten abhängt, das es ermöglicht, verschiedenartigen Antrieben zu genügen und so die Gerichtetheit und Konsequenz des Verhaltens während der Prozesse der Aufgabenerfüllung aufrechtzuerhalten.

Ein Studium des Interesses und der inneren Einstellung ist wichtig bei dem Leistungsabfall. Es herrscht erhebliche Verwirrung in der Definition dieser beiden Begriffe und in bezug auf ihre Rolle in der Antriebspsychologie. Neuere theoretische und experimentelle Studien, die diese Unklarheit beseitigen, betrachten die Einstellung als ganz unabhängig von der momentanen Antriebslage des Organismus. Interesse wird andererseits verstanden als kognitive Vorwegnahme verschiedener Handlungen und Wirkungen des Organismus in Verbindung mit seiner augenblicklichen Antriebslage. Entsprechend darf das Interesse als ein Mechanismus aufgefaßt werden, der die Antriebsströme während der Prozesse der Aufgabenausführung reguliert. Leistungsabnahme auf Grund eines Schwundes an ursprünglicher Antriebsstärke zieht auch ein entsprechend vermindertes Interesse nach sich.

Eigene Experimente

Zweistündige fortlaufende Ausführung von Werkarbeit und schwierigen geistigen Aufgaben, die mit denen des Werkarbeitsprogramms des „Grundunterrichts" verwandt sind, variieren in ihrem Schwierigkeitsgrad und geben so Gelegenheiten zu unterschiedlicher Ausprägung von Varabilität des Verhaltens. Werkarbeit mit ihrem relativen Reichtum an Schwierigkeiten bietet eine Menge von Problemsituationen. Tätigkeit unter diesen Bedingungen schützt das Individuum vor unerfreulicher Monotonie und Langeweile. Sie kann lange Zeit hindurch viele Bedürfnisse befriedigen und ist daher interessant. Umgekehrt befriedigen Aufgaben von vergleichsweise weniger verwickelter und abwechslungsreicher Art genügend starken Antrieben nicht und führen daher zu Leistungsschwund.

Eingehende Versuche, die mit Schülern der 5. Klasse von Volksschulen in Uppsala unternommen wurden, haben die theoretischen Überlegungen bestätigt. Die Versuchspersonen wurden vor, während und nach einer zweistündigen Arbeitsperiode kontrolliert. Ein zehnminütiger Test unter Bedingungen, die denen bei der Aufgabenerledigung ähnelten und sie ersetzten, wurde je vor und nach der kontinuierlichen Arbeit abgehalten. Während der Ausführung der Aufgaben prüften die Schüler ihre Arbeit in gleichbleibenden Intervallen von je 20 Minuten daraufhin, wie sie ihnen gefiel.

In der ersten Versuchsreihe hatte eine Gruppe zweistündig fortgesetzte Werkarbeit, und eine weitere parallele Gruppe löste einfache arithmetische Aufgaben. Eine ziemlich komplizierte und abwechslungsreiche Aufgabe wurde auf diese Weise mit einer eintönigen verglichen. Die Resultate zeigen, daß bei der Werkarbeitsgruppe sowohl Leistung wie Interesse zunahmen. Bei der anderen Gruppe zeigten sich indessen gegenteilige Ergebnisse.

In der nächsten Versuchsreihe wurde die hauptsächliche Werkaufgabe einer zweistündigen sehr monotonen Werkaufgabe gegenübergestellt und die monotone arithmetische Aufgabe einer schwierigen zweistündigen Denkaufgabe (z. B. eine zweistündige schwierige Lektion über „Weihnachten" und eine weitere über „Schiff"). Die vorigen Ergebnisse wurden bestätigt. Eintönige Arbeit sowohl körperlicher wie geistiger Art zieht Nachlassen des

Interesses und der Leistung nach sich, und bei schwierigen Aufgaben findet man entgegengesetzte Resultate.

In der dritten Versuchsreihe wurden die Experimente in der gleichen Weise durchgeführt wie in der zweiten, mit der einen Abweichung, daß die Versuche eine Woche lang täglich wiederholt wurden. Die Ergebnisse jedes einzelnen Tages fielen mit jenen der zweiten Reihe zusammen. Zudem nahmen bei eintönigen Aufgaben Interesse und Leistung von Tag zu Tag ab. Bei schwieriger Werkarbeit ist das Interesse vom ersten Tage an die ganze Woche hindurch maximal. Die Arbeitsleistung wächst von Tag zu Tag. Bei komplizierten geistigen Aufgaben nimmt ebenfalls Interesse und Leistung täglich zu.

Daher scheint es, daß aufs Ganze gesehen die Leistungsveränderungen primär als Veränderungen der Antriebslage erklärt werden können. In zweistündiger kontinuierlicher und abwechslungsreicher Aufgabenausführung von mäßiger Belastendheit (Intensität) wird das Interesse wachgehalten, und die Leistung läßt nicht nach, sondern steigt stattdessen gewöhnlich. Daher darf geschlossen werden, daß vom Blickpunkt der „Ermüdung" aus, die in dieser Arbeit untersucht wird, keine Einwände gegen die Aufnahme zweistündiger kontinuierlicher manueller Tätigkeit der beschriebenen Art in das „Grundunterrichtsprogramm" in Indien zu machen sind.

ABBREVIATIONS

Ach	Acetyl choline
ATP	Adenosine triphosphate
B.	Breadth
Cal.	Calorie
cl	Chlorine
Co_2	Carbon di-oxide
D	Drive
E. L.	Endurance Limit
${}_sE_r$	Reaction potential
epp	end-plate potential
F°	Degrees in Fahrenheit
gm.	Gram
I_r	Reaction inhibition
${}_sI_r$	Conditioned inhibition
$\dot{I}_r$	$I_r + {}_sI_r$
K	Potassium
L.	Length
Mg.	Milligram
ml.	Millilitre
mm.	Millimeter
Na	Sodium
O_2	Oxygen
P_aO_2	Partial pressure of oxygen in arterial blood
$Pa\ Co_2$	" " carbon di-oxide " "
Pc	Phosphocreatine
RPS	Recovery pulse sum
R. Q.	Respiratory Quotient
R. T.	Reaction time
Sec.	Seconds
T.	Thickness
%	Percent
Abn.	Abnormal

Acad.	Academy
Agri.	Agriculture
Allg.	Allgemeine
Amer.	American
A. M. A.	American Medical Association
Ann. Rev.	Annual Review
Anat.	Anatomy, Anatomie, Anatomical
Appld.	Applied
Arch.	Archives
Assn.	Association
Biochem.	Biochemical
Biophys.	Biophysics
Brd.	Board
Brit.	British
Bull.	Bulletin
Calif.	California
Cambr.	Cambridge
Canad.	Canadian
Cell.	Cellular
Charac.	Character
Clin.	Clinical
Cold spr. hrb. symp. quant. biol.	Cold spring harbour symposium on quantitative biology
Comp.	Comparative
Cytol.	Cytology
Dept.	Department
Dis.	Disease
Edn., Educ.	Education, Educational
EEG.	Electroencephalography
Exper.	Experimental
Fat.	Fatigue
Fed.	Federation
Genl.	General
Genet.	Genetic
Govt.	Government
Hlth.	Health
Hyg.	Hygiene
Ind., Industr.	Industrial, Industry

Intern.	International
Invest.	Investigation
J.	Journal
Jr.	Junior
Jt.	Joint
Lab.	Laboratory
Med.	Medica, Medical, Medicine
Ment.	Mental
Monogr.	Monograph
Nat.	National
Nerv.	Nervous
Neurol.	Neurology
Neuorosurg.	Neurosurgery
Ortho.	Orthopedics
Phil., philos.	Philosophy, Philosophical
Phys.	Physical
Physiol.	Physiologica, Physiologie, Physiological, Physiology
Proc.	Proceedings
Psychiat.	Psychiatry
Psychol.	Psychologica, Psychologie, Psychological, Psychology
Publ.	Publication
Quart.	Quarterly
Rep.	Reports
Res.	Research
Revs.	Reviews
Roy.	Royal
Scand., Skand.	Scandinavica, Scandinavia, Scandinavian
Sci.	Science, Sciences
Secrt.	Secretariat
Ser.	Serie
Soc.	Society, Social
Social.	Sociological
Suppl.	Supplementary, Supplements
Trans.	Transactions
Univ., uni.	University
U. S.	United States
Zsch., Zeitschr.	Zeitschrift

LITERATURE

(Items are included which are not quoted in the text, since the author has found these extremely useful in understanding the wider aspects of the problem in the course of giving the thesis its present form.)

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